

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN TUOZHU TECHNOLOGY CO., LTD.,

Petitioner

v.

STRATASYS, INC.

Patent Owner.

PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 9,592,660

Case No. IPR2025-00257

DECLARATION OF DR. TIM A. OSSWALD

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EXHIBIT LIST

Exhibit	Description
2010	Transcript of the Deposition of Dr. Michael Hickner
2011	Temperature Sensors – RTD (Resistance Temperature Detector), Digi-Key Electronics, https://web.archive.org/web/20161217230700/https://www.digikey.com/products/en/sensors-transducers/temperature-sensors-rtd-resistance-temperature-detector/535
2012	Temperature Sensors - Thermostats - Solid State, Digi-Key Electronics, https://web.archive.org/web/20170210040250/http://www.digikey.com/products/en/sensors-transducers/temperature-sensors-thermostats-solid-state/564
2013	Temperature Sensors, Analog and Digital Output, Digi-Key Electronics, https://web.archive.org/web/20161217200813/http://www.digikey.com/products/en/sensors-transducers/temperature-sensors-analog-and-digital-output/518
2014	Technical Data Sheet, Eastman Tritan™ Copolyester TX1000, Eastman Chemical Co., July 15, 2020
2015	Dinwiddie, R., et al. (2013), Real-time Process Monitoring and Temperature Mapping of a 3D Polymer Printing Process: Infrared Imaging of the Polymer 3D-Printing Process, Proceedings of SPIE - The International Society for Optical Engineering
2016	Hua, T. et al., Research on molten pool temperature in the process of laser rapid forming, J. of Materials Processing Technology 198 (2008) 454-462
2017	Shreir, L. L., et al., Corrosion: Corrosion Control, Vol. 2 (1976), pp. 15:81-15:92, 22:3-22:16, Index

I. INTRODUCTION

1. My name is Tim A. Osswald, and I declare as follows:

2. I am a citizen of the United States and am over 18 years of age. I have personal knowledge of the matters stated in this declaration.

3. I have been asked to provide technical assistance in the *inter partes* review of U.S. Patent No. 9,592,660, which I may abbreviate as “the ’660 Patent” or refer to as the “Challenged Patent.” I understand that this patent was formerly owned by Stratasys, Inc. (“Stratasys”). This declaration is a statement of my opinions on issues related to the patentability of claims of the Challenged Patent.

A. Qualifications and Experience

4. I am a Professor Emeritus at the University of Wisconsin-Madison in the Department of Mechanical Engineering, where I was the Co-Director of the Polymer Engineering Center. I am also an Honorary Professor of Plastics Technology at the University of Erlangen-Nuremberg in Germany and the National University of Colombia.

5. I earned both a Bachelor of Science degree (1981) and a Master of Science degree (1982) in Mechanical Engineering from the South Dakota School of Mines & Technology. I also earned a Ph.D. (1987) in Mechanical Engineering from the University of Illinois at Urbana-Champaign. My Ph.D. research was in the field of polymer processing.

6. From 1987 to the present, I have held a variety of professional and academic positions. I was a consultant for the Dynamit Nobel Research Center in Leverkusen, Germany, as well as a Humboldt Fellow at the Institute for Plastics Processing at the Technical University of Aachen, Germany between 1987 and 1989. In 1989, I joined the Mechanical Engineering Department at the University of Wisconsin-Madison as an Assistant Professor. I became a Full Professor in 1999.

7. I have extensive experience with polymer part manufacturing processes and extensive experience with behavior and characterization of polymeric materials, including thermoplastics, thermosets, and rubber. I have in-depth knowledge in various polymer processing techniques, such as extrusion and molding processes, as well as composites manufacturing and additive manufacturing (also known as 3-D printing). I have in-depth knowledge of additive manufacturing and additive manufacturing patent history.

8. I am a member of numerous professional societies and organizations. For example, I am a member of the Society of Plastics Engineers, the Scientific Alliance of the University Professors of Polymer Technology, the Polymer Processing Society (where I currently serve as Treasurer), and the German Technical Journalists Organization (DFJV).

9. For over 30 years, I have conducted research and taught classes in the field of mechanical engineering, and more specifically regarding polymer and

composite materials and polymer and composite processing. My research has focused on polymer and polymer composites processing, polymer and polymer composites materials science, and engineering design with polymers and polymer composites. Furthermore, I regularly serve as a consultant to the plastics industry and have extensive experience dealing with additive manufacturing and design and manufacture of additive manufacturing equipment. I am currently part of the Scientific Advisory Board for SABIC Specialties, and the Scientific Advisory Council of SABIC, a large chemical company. I also served on the Technical Advisory Board of Teel Plastics, a pipe extrusion company, and the Madison Group, a plastics consulting firm.

10. Since February of 2019, I have served as an Advisory to the Colombian President on matters regarding science and technology, and the creation of a new Ministry of Science, Technology, and Innovation.

11. At the University of Wisconsin-Madison, I developed and taught a variety of courses, including Polymer Manufacturing Processes, Introduction to Transport Phenomena in Polymer Engineering, Engineering Design with Polymers, Modeling and Simulation in Polymer Processing, Introduction to Polymer Additive Manufacturing and Introduction to Polymer Composites Processing. My courses include units on fundamental aspects of polymer engineering, such as melting, solidification, and flow, as well as processing techniques such as injection molding,

extrusion processes, additive manufacturing, composites processes and secondary operations such as thermoforming, blow molding, film casting, film blowing, joining, and welding. In my additive manufacturing course, I teach a whole unit on intellectual property in additive manufacturing, as well as the underlying physics that govern the various additive manufacturing processes.

12. In addition to my teaching and research duties at the University of Wisconsin-Madison, twice a year I taught a Modeling and Simulation in Polymer Processing course at the University of Nuremberg-Erlangen in Germany. Since 2020 I teach the course Simulation of Polymer Additive Manufacturing Processes at the University of Nuremberg-Erlangen in Germany. I have also taught the Materials Science of Polymers for Engineers and Polymer Processing courses at the EAFIT University and the National University in Colombia, and the course Polymer Additive Manufacturing at the Universidad de Los Andes in Bogotá, Colombia.

13. Over the years, my research and teaching have led to the issuance of seven patents, including patents in the field of additive manufacturing, as well as several honors, and awards. For example, in 2001 I was the recipient of the VDI-K (German Engineering Society – Plastics) Dr. Richard Escales Prize; in 2006, I was named Honorary Professor at the University of Erlangen-Nuremberg in Germany, and in 2010 I was named Honorary Professor at the National University of Colombia; in 2016, I was named Educator of the Year by the Society of Plastics Engineers

(SPE); and in 2017, the same organization named me Educator of the Year in the Field of Composites.

14. I have also published over 400 papers in the field of polymer engineering and have authored 11 books in the area: Polymer Materials Science for Engineers (Hanser Publishers, 1st Edition 1996, 2nd Edition 2003, 3rd Edition 2012), Polymer Processing Fundamentals (Hanser Publishers, 1998), Injection Molding Handbook (Hanser Publishers, 1st Edition 2001, 2nd Edition 2006), Compression Molding (Hanser Publishers, 2003), Polymer Processing – Modeling and Simulation (Hanser Publishers, 2006), Plastics Handbook (Hanser Publishers 2006, 2019), Kunststoff-Taschenbuch (Hanser Publishers 2006, 2013, 2022), Plastics Testing and Characterization (Hanser Publishers, 2007), Understanding Polymer Processing (Hanser Publishers, 1st Edition 2010, 2nd Edition 2017, 3rd Edition 2025), and Discontinuous Fiber-Reinforced Composites – Fundamentals and Applications (Hanser Publishers, 2020). Some of my books have been translated into Chinese, Japanese, Spanish, Italian, Farsi, and Russian. I am also the series editor for the Plastics Pocket Power Series of Hanser Publishers. I am one of the authors of the “Plastics Handbook – The Resource for Plastics Engineers,” (“Plastics Handbook”) published by Hanser Publishers, which came out in its 5th edition in 2019. I am also one of the co-authors of the German version of the Plastics Handbook, which was published in its 32nd edition in 2022. The Plastics Handbook is a complete

compendium of polymer materials, polymer processes and polymer characterization techniques. The processing chapter presents the major additive manufacturing techniques. While the Plastics Handbook is a book for practitioners and engineers, some of my other books are polymer engineering textbooks that are used in courses taken by undergraduate and graduate students throughout the world. One such book is Understanding Polymer Processing, which contains a chapter on additive manufacturing. Other books are more advanced, and are used by researchers at universities and in the industry to acquire in-depth knowledge in polymer engineering.

15. My academic and professional background and qualifications are further elaborated in my curriculum vitae (Appendix A).

B. Compensation

16. I am being compensated at my normal rate of \$700 per hour for my analysis, plus reimbursement for expenses. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

C. Scope of Work and Materials Considered

17. This declaration is based on my education, personal knowledge, and professional and academic experience in the area of three-dimensional printing.

18. I have been asked to review the Challenged Patent and its prosecution history, to provide an understanding of the technology relevant to the Challenged

Patent, to review certain prior-art references, and to analyze whether or not those references disclose or teach limitations of claims from the Challenged Patent.

19. The opinions stated in this declaration are from the perspective of a Person of Skill in the Art (POSITA) as of December 17, 2014, whose qualifications and abilities are described below.

20. In forming my opinions, I have reviewed the Challenged Patent, its prosecution history, the materials cited in the List of Exhibits, and the materials cited throughout my declaration. I have also relied on my academic and professional experience in reaching the opinions expressed in this declaration.

II. THE CHALLENGED CLAIMS OF THE '660 PATENT

21. I understand that Petitioner has challenged claims 1–15 of the '660 Patent (the “Challenged Claims”). The Challenged Claims are set forth below, with some claim elements further sub-divided for ease of reference:

Claim Element	Claim Language from '660 Patent
1.pre (preamble)	1. A build apparatus for printing a 3D object of thermoplastics employing additive manufacturing methods, the apparatus comprising:
1.a	a build platform with a temperature control unit configured to control heating of the build platform;
1.b	a thermally conductive plate disposed adjacent to the build platform; and
1.c	a polymer coating attached to a surface of the thermally conductive plate which is capable of

Claim Element	Claim Language from '660 Patent
1.c.i	(i) facilitating adhesion to the 3D object during printing
1.c.ii	(ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object
1.c.iii	wherein the polymer coating is not a polymer tape.
2	2. The build apparatus of claim 1, wherein the polymer coating is a polyimide.
3	3. The build apparatus of claim 1, wherein the temperature control unit comprises heater cartridges that are spaced along a surface of the build platform.
4	4. The build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.
5	5. The build apparatus of claim 1, further comprising a ceramic or high temperature dielectric that insulates the build platform.
6	6. The build apparatus of claim 1, wherein the build platform, the thermally conductive plate, and the polymer coating are able to withstand high temperature ranging between 150 degree Celsius and 300 degree Celsius.
7	7. The build apparatus of claim 1, wherein the material for the thermally conductive plate comprises one or more of aluminum, steel, brass, ceramic, glass, or alloys with a low coefficient of thermal expansion (CTE).

Claim Element	Claim Language from '660 Patent
8	8. The build apparatus of claim 1, wherein the material for the build platform comprises one or more of aluminum, steel, brass, ceramic, glass, or alloys with a low coefficient of thermal expansion (CTE).
9	9. The build apparatus of claim 1, wherein the thermally conductive plate thickness ranges from 0.025-0.5" and wherein the thickness is selected depending on the flexural character of the material.
10	10. The build apparatus of claim 1, wherein the thickness of the polymer coating ranges from 0.001" to 0.1".
11	11. The build apparatus of claim 1, wherein a surface of the polymer coating includes nano-, micro-, or milli-meter scale features that increase adhesion to the 3D object.
12	12. The build apparatus of claim 1, wherein the thermally conductive plate is flexible so as to allow for easier dissociation between the 3D object and the thermally conductive plate upon cooling and reduce damage to the polymer coating or the 3D object during removal of the 3D object.
13	13. The build apparatus of claim 1, wherein the temperature control unit is a heater cartridge.
14	14. The build apparatus of claim 1, wherein the build platform has a first coefficient of thermal expansion (CTE) and the thermally conductive plate has a second CTE, wherein the first CTE is greater than the second CTE.
15	15. The build apparatus of claim 1, wherein the thermally conductive plate is non-magnetically secured to and removable from the build platform.

III. LEVEL OF ORDINARY SKILL IN THE ART

22. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to the Challenged Patent as well as the level of ordinary

skill in that art at the time of the claimed invention. The “art” is the field of technology to which the patent is related.

23. I have been instructed by counsel that the person of ordinary skill in the art (“**POSITA**”) is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. I further understand that a person of ordinary skill in the art is determined by looking at (1) the type of problems encountered in the art; (2) the prior-art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

24. In my opinion, a person of ordinary skill in the art with respect to the ’660 Patent is someone with bachelor’s degree in Mechanical Engineering, Chemical Engineering, Materials Science, or a comparable field and at least two years of experience related to 3D printing, with additional experience potentially being a substitute for a formal degree or training (and vice versa).

25. I understand that Petitioner and Petitioner’s expert, Dr. Hickner, have proposed a somewhat different level of ordinary skill in the art. Specifically, they assert that a person of ordinary skill in the art “would have included a bachelor’s degree in Mechanical Engineering, Chemical Engineering, Materials Science, or a comparable field and at least two years of experience (e.g., research or industry

experience) related to 3D printing.” EX1003 (Declaration of Dr. Hickner), ¶28; Pet. at 7. My opinions in this declaration would not change under this proposed level of ordinary skill in the art.

26. As of at least December 17, 2014, which I understand is the filing date of the '660 Patent, I had at least the level of skill required under either my or Dr. Hickner's definitions of a person of ordinary skill in the art and, in rendering my opinions, have viewed the '660 Patent from the perspective of a person of ordinary skill in the art.

IV. LEGAL STANDARDS

27. I am not a legal expert. In presenting my opinions, I have applied the legal standards provided to me by counsel in arriving at the opinions set forth in this declaration.

28. I understand that in this *inter partes* review proceeding, the Petitioner has the burden of proving that the claims of a Challenged Patent are unpatentable in light of the prior art by a preponderance of the evidence. I understand that a preponderance of the evidence is evidence sufficient to show that a fact is more likely true than not true.

A. Legal Standard for Claim Construction

29. I understand that the first step in determining whether a patent claim would have been anticipated or obvious is to ascertain how a POSITA would have understood the claim terms.

30. I have been instructed by counsel on the law regarding claim construction and patent claims. I understand that a patent may include two types of claims: independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim, or it can further depend from another dependent claim. I understand that a dependent claim includes all the limitations that it recites, as well as all the limitations recited in the claim(s) from which it depends.

31. It is my understanding that in proceedings before the PTAB, the claims of a patent are to be construed under what is referred to as the “*Phillips* standard.” I understand that this means that claim terms of a patent are given the meaning the terms would have to a POSITA, in view of the description provided in the patent itself and the patent’s file history.

32. I understand that to determine how a person of ordinary skill would understand a claim term, one should look to those sources available that show what a person of skill in the art would have understood the disputed claim language to mean. These sources include the words of the claims themselves, the rest of the

patent's description, the prosecution history of the patent (all of which considered "intrinsic" evidence), and "extrinsic" evidence concerning relevant scientific principles, the meaning of technical terms, the technical literature on established and emerging relevant technologies, and the state of the art at the time of the invention.

33. I understand that, in construing a claim term, one looks primarily to the intrinsic evidence, including the words of the claims themselves, the remainder of the patent, and the patent's prosecution history.

34. I understand that extrinsic evidence, which is evidence external to the patent and the prosecution history, may also be useful in interpreting patent claims when the intrinsic evidence itself is insufficient.

35. I understand that words or terms should be given their ordinary and accepted meaning unless it appears that the inventors were using them to mean something else. In making this determination, the claims, the remainder of the patent, and the prosecution history are of principal importance. Additionally, the patent and its prosecution history must be consulted to confirm whether the patentee has acted as its own lexicographer (i.e., provided its own special meaning to any disputed terms), or intentionally disclaimed, disavowed, or surrendered any claim scope.

36. I understand that the claims of a patent define the scope of the rights conferred by the patent. The claims particularly point out and distinctly claim the subject matter which the patentee regards as his invention. Because the patentee is

required to define precisely what he claims his invention to be, it is not proper to construe claims in a manner different from the plain import of the terms as used in the patent. Accordingly, a claim construction analysis must begin and remain centered on the claim language itself. Additionally, the context in which a term is used in the asserted claim can be highly instructive. Likewise, other claims of the patent in question, both challenged and un-challenged, can inform the meaning of a claim term. For example, because claim terms are normally used consistently throughout the patent, the usage of a term in one claim can often illuminate the meaning of the same term in other claims. Differences among claims can also be a useful guide in understanding the meaning of particular claim terms.

37. I understand that a person of ordinary skill in the art is deemed to read a claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the remaining text and figures. For this reason, the words of the claim must be interpreted in view of the entirety of the patent specification (i.e., the claims, remaining text, and figures). The written description (figures and remaining text) is the primary basis for construing the claims and provides a safeguard such that correct constructions closely align with the patent.

38. In addition to consulting the patent itself, I understand that one should also consider the patent's prosecution history. The prosecution history provides

evidence of how both the Patent Office and the inventors understood the terms of the patent, particularly in light of what was known in the prior art.

39. I understand that while intrinsic evidence is of primary importance, extrinsic evidence, e.g., all evidence external to the patent and prosecution history, including expert and inventor testimony, dictionaries, and learned treatises, can also be considered. Extrinsic evidence should not be considered, however, divorced from the context of the intrinsic evidence. Furthermore, while extrinsic evidence can shed useful light on the relevant art, it is less significant than the intrinsic record in determining the legally operative meaning of claim language.

B. Legal Standard for Prior Art

40. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim.

41. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims of the Challenged Patent without undue experimentation. I understand that a patent issued by the United States Patent and Trademark Office is presumed to provide an enabling disclosure. Factors to consider in determining whether undue experimentation is needed are: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of

those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims.

42. I understand that for a prior-art reference to be considered for obviousness, the reference must be “analogous.” I understand that the comparison for purposes of determining “analogous” is between the asserted prior-art reference and the Challenged Patent. I have been further informed that for a prior-art reference to be considered “analogous” to the Challenged Patent and thus available as prior art for obviousness, at least one of the following conditions must be met: (1) the reference is from the same field of endeavor as the Challenged Patent, even if it addresses a different problem; or (2) the reference is reasonably pertinent to the particular problem the Challenged Patent is concerned with, even if it is not within the same field of endeavor.

C. Legal Standard for Patentability

43. I understand that for an invention claimed in a patent to be found patentable, it must be (among other things) new and not obvious based on what was known before the invention was made.

44. I understand that, once the claims of a patent have been properly construed, the second step in determining patentable of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

45. I understand that for purposes of this declaration, there are two ways to demonstrate that a patent claim is not patentable. A patent claim can be anticipated, or a patent claim can be obvious. I address each of these below.

1. Anticipation and Inherency

46. I understand that prior art can “anticipate” the claims of an asserted patent. It is my understanding that in order for a claim to be anticipated by the prior art, every element of that claim must be found, explicitly or inherently, in a single prior art reference. In other words, to determine whether a single prior art reference anticipates a patent claim, one should consider not only what is expressly disclosed in that reference, but also what inherently occurred as a natural result of the practice of the system or method disclosed in that prior art reference.

47. It is further my understanding that to establish such inherency, the missing descriptive matter must be necessarily present in the item of prior art and that it would be so recognized by persons of ordinary skill in the art. It is also my understanding that such inherency may be shown through extrinsic evidence.

2. Obviousness

48. I understand that the prior art may render a patent claim “obvious.” I understand that two or more prior art references (e.g., prior art articles, patents, or publications) that each disclose fewer than all elements of a patent claim may nevertheless be combined to render a patent claim obvious if the combination of the

prior art collectively discloses all elements of the claim and one of ordinary skill in the art at the time would have been motivated to combine the prior art in such a way with a reasonable expectation of success.

49. I understand that this motivation to combine need not be explicit in any of the prior art, but it may be inferred from the knowledge of one of ordinary skill in the art at the time the patent was filed. I also understand that one of ordinary skill in the art is not an automaton but is a person having ordinary creativity. I further understand that an obviousness analysis recognizes that market demand often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace. I further understand that one or more prior art references, articles, patents or publications that disclose fewer than all of the elements of a patent claim may render a patent claim obvious if including the missing element would have been obvious to one of skill in the art (e.g., the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system).

50. I understand that a person of ordinary skill in the art provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents a person of ordinary skill from using hindsight in deciding whether a claim is obvious.

51. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the challenged claims, (3) the level of ordinary skill in the pertinent art, and (4) when in evidence, the existence of secondary considerations (such as commercial success, long-felt but unresolved needs, failure of others, etc.) to the extent they exist and have a nexus to the claimed invention.

52. I am informed that secondary indicia of non-obviousness (also known as secondary considerations) may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success or lack of commercial success of processes covered by the patent; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art; (5) taking of licenses under the patent by others; and (6) deliberate copying of the invention. I also understand that there must be a relationship between any such secondary indicia and the invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination. I also understand that secondary considerations are given less weight when the alleged invention represents a relatively small advance in a crowded field with predictable results. I further understand that the patentee has the burden of coming forward with evidence of the relationship between any

secondary consideration of non-obviousness and the claimed invention (also known as the “nexus”).

53. It is also my understanding that there are additional considerations that may be used as further guidance as to when the above factors will result in a finding that a claim is obvious, including the following:

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;
- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;
- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent’s claims; and
- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

54. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue

the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

55. I further understand that a claim may be deemed invalid for obviousness in light of a single prior art reference, without the need to combine references, if the elements of the claim that are not found in the reference can be supplied by the knowledge or common sense of one of ordinary skill in the relevant art.

56. I also understand that practical and common-sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I further understand that a person of ordinary skill in the art looking to overcome a problem will often be able to fit the teachings of multiple publications together like pieces of a puzzle, although the prior art need not be like two puzzle pieces that must fit perfectly together. I understand that an obviousness analysis therefore considers the inferences and creative steps that a person of ordinary skill in the art would employ under the circumstances.

57. I understand that a person of ordinary skill could have combined two pieces of prior art or substituted one prior art element for another if the substitution can be made with predictable results, even if the swapped-in element is different from the swapped-out element. I understand that the relevant question is whether prior art techniques are interoperable with respect to one another, such that a person

of skill would view them as a design choice, or whether a person of skill could apply prior art techniques into a new combined system.

58. In sum, my understanding is that prior art teachings are properly combined where a person of ordinary skill in the art having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

V. THE '660 PATENT AND THE CHALLENGED CLAIMS

A. Summary of the '660 Patent (EX1001)

59. I have reviewed the '660 Patent, which relates to “the field of 3D printing of objects” and “a heated build platform for supporting the three dimensional objects using high temperature polymers.” EX1001, at 1:7-10.

60. The '660 Patent explains that the use of “polyimide tape or ultem plates does not meet the thermal requirements for high temperature thermoplastics” EX1001, at 1:34-40.

61. “When using high temperature thermoplastics during fused filament fabrication, a heated build plate and a tacky surface are necessary to maintain

adhesion between the plate and bottom layer of the printing part.” EX1001, at 1:40-44.

62. “If the build plate does not have a tacky surface then the polymer will slide along the plate or stick to extruding nozzle.” EX1001, at 1:46-48.

63. The specification of the ’660 Patent discloses several issues with polyimide tape, which has been applied to “heated build plates for its tactility and performance under high temperatures.” EX1001, at 1:49-50.

64. Application of polyimide tape allows for “tiny debris or air to be trapped” between the tape and surface, which when heated, allows “the air gaps [to] expand creating an uneven printing surface.” *Id.* at 1:53-54. Under high temperatures, the adhesive for the polyimide tape can “burn off . . . releasing fumes and damaging the coating.” *Id.* at 1:54-56.

65. After a part is made, the specification of the ’660 Patent also describes several issues with polyimide tape during removal of the part. In particular, the “tape can be easily damaged upon removal of the part.” EX1001, at 1:57-59. At elevated temperatures, the “bottom layer of tape can permanently adhere to the 3D part causing the tape to tear or bubbles to form between the tape and build plate.” *Id.* at 1:59-62. And when cooled, the “polyimide tape can still adhere to the bottom layer resulting in damage or tearing of the tape upon part removal.” *Id.* at 1:62-64.

66. Unlike the use of polyimide tape to coat a plate, the '660 Patent discloses a high temperature polymer coating 106 that “provides adhesion between the 3D object and the surface of the plate 104” to provide “a consistent, smooth, tacky, long-lasting surface for the construction of 3D objects via FFF and continuous fiber deposition.” *Id.* at 5:56-58, 5:61-66. “[T]he polyimide coating 106 has demonstrated better adherence properties both to the bottom layer of a 3D object and the plate 104 over the currently used polyimide tape.” *Id.* at 6:4-7. The '660 Patent teaches that coating 106 “is much more resilient compared to polyimide tape, which can be easily scratched or punctured.” *Id.* at 6:7-8. Further, the “polyimide coating 106 does not wear away and thus does not need to be replaced” whereas “polyimide tape is preferably replaced after every build under high temperature build platform temperatures.” *Id.* at 6:10-15. Additionally, the coating 106 “is applied to a clean plate minimizing or eliminating the potential for trapped debris or air bubbles between the coating 106 and removable plate surfaces 104.” *Id.* at 6:15-18.

67. The '660 Patent illustrates and describes figures that further detail its solution. Figure 1 shows a build apparatus (100) that includes a build platform (102), thermally conductive plate (104), and a high temperature polymer coating (106).

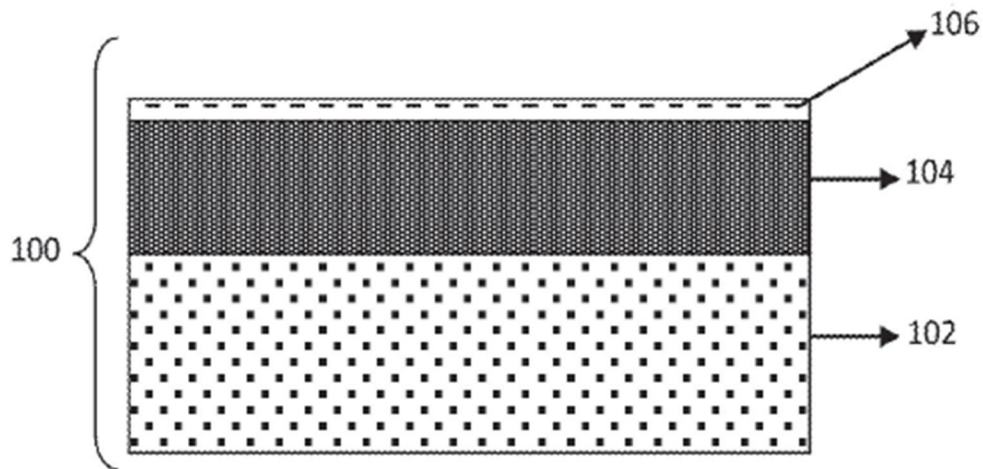


FIG. 1

EX1001, at Fig. 1, 3:17-20. The '660 Patent explains that the build platform (102) includes temperature control to evenly heat the surface of the platform. *See id.* at 3:20-29. The build platform (102) can be a material such as “aluminum, steel, brass, ceramic, glass, or allows similar with low coefficient of thermal expansion (CTE).” *Id.* at 3:28-30. As shown, “high temperature polymer coating (106) is applied directly over the surface of removable plate (104).” *Id.* at 4:30-32. “In an embodiment, a high temperature polymer coating 106 is spray coated over the plate 104.” *Id.* at 4:30-32. Application to “a clean plate . . . further minimizes or eliminates the potential for occurrence of trapped debris or air bubbles between the coating 106 and the plate surface 104.” *Id.* at 4:33-35. The high temperature

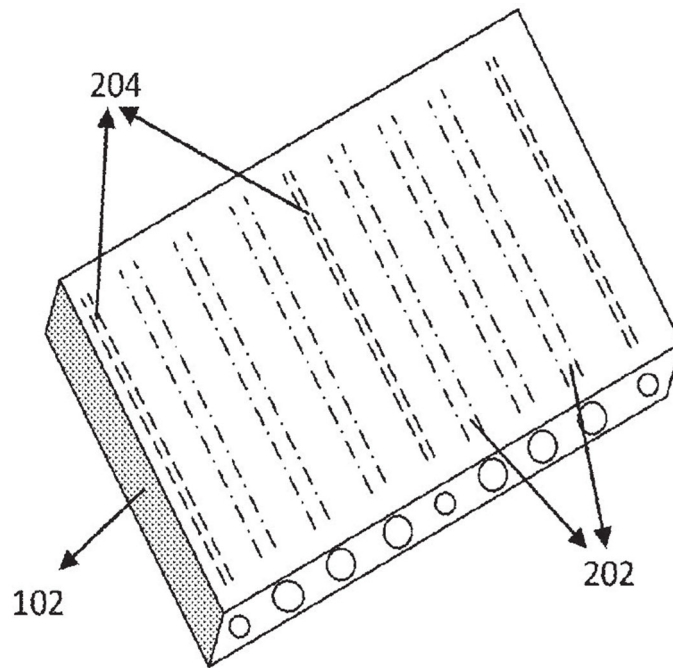
polymer used for coating may be polyimide. *Id.* at 4:32-33. The '660 Patent explains that coating 106 “provides a tacky surface preventing the extrudate (material extruded from the nozzle) from sliding along the plate 104 or sticking to extruding nozzle.” *Id.* at 4:44-47. In addition, the coating (106) is “resilient in nature and cannot be easily scratched or punctured” and its “surface toughness . . . prevents damage from occurring during 3D object removal.” *Id.* at 4:47-51. Further, “the high temperature polymer coating 106 does not wear away and thus does not need to be replaced after every build under high temperature.” *Id.* at 4:52-54.

68. “[T]o increase polymer adhesion to the plate surface 104 coated with the high temperature polymer 106, the surface of the high temperature polymer coating 106 may be roughened or treated.” *Id.* at 4:61-64. Such treatment “imparts a regular or an irregular patterned feature to the coating 106.” *Id.* at 4:64-66. Further, “the surface of the high temperature polymer coating 106 may be roughened at the nano-, micro-, or milli-meter scale using methods like and not limited to sand blasting, bead blasting, and/or metal wire brushing to increase polymer adhesion to the coated surface 106.” *Id.* at 4:66-5:4.

69. The '660 Patent explains that “removable plate 104 must be thermally conductive in nature, so that it may be heated up due to the heat generated at the build platform 102 because of the temperature control means.” *Id.* at 3:57-60. For

example, “the material of the plate 104 may be thin ceramic, which is thin enough to still conduct heat” *Id.* at 5:43-46. The ’660 Patent explains that the plate (104) “must not be too thin such that heating of the plate produces rippling, bowing, or warping of the plate, resulting in a print surface that is uneven or not consistently level.” *Id.* 4:5-7. In addition, “the material for the removable plate 104 may be aluminum, steel, brass, ceramic, glass, or alloys similar with low coefficient of thermal expansion (CTE).” *Id.* at 3:63-66. The ’660 Patent explains that “a material having a low coefficient of thermal expansion (CTE)” avoids “expansion of the plate as it is heated up due to the heated build platform 102.” *Id.* at 3:60-63. In addition, the “low coefficient of thermal expansion (CTE) of the plate 104 favors an even flat surface for printing.” *Id.* at 5:32-33. The “plate 104 will bow or deform and actually separates from the build platform 102” if “the material of the plate 104 has a much higher CTE than the build platform 102 below it.” *Id.* at 5:33-37. As a result, “the surface for printing a 3D object, which is the surface of the removable plate 104, will become uneven and hence, the printing process doesn’t have a flat surface to print on.” *Id.* at 5:37-40.

70. Figure 2 of the ’660 Patent shows a build platform (102) with holes for heater cartridges (202) and thermocouples (204).



EX1001, Fig. 2, 2:47-49, 3:32-34. The '660 Patent explains that the “number of holes depends on the number of heating cartridges and/or thermocouples.” *Id.* at 4:44-46. As shown, “the heater cartridges are spaced evenly along the surface of the build platform 102, comprising, for example, an aluminum block.” *Id.* at 3:34-37. “[F]or controlling temperature of the build platform (102), one or more thermocouples can be situated at one or several locations (204) on the block 102 to provide feedback to a controller, such as a PID controller, and hence maintain temperature set points throughout a build.” *Id.* at 3:37-42. Thus, the “surface of the build platform (102) is evenly heated using the temperature control means.” *Id.* at 3:22-23; *see also id.* at 3:23-29. In addition, “a ceramic, or other high temperature

dielectric, can be used to insulate the build platform 102 and protect build platform support 102 from emitted heat.” *Id.* at 3:42-44.

B. Summary of the Prosecution History of the ’660 Patent (EX1002)

71. I reviewed the prosecution history of the ’660 Patent (EX1002). During prosecution, I understand that the examiner rejected pending claims 1, 3, 5, 7-11, 13, 15, and 17-18 as anticipated by Comb. EX1002, at 103; *see also id.* at 97-108 (July 14, 2016 Office Action).

72. Thereafter, I understand that the applicant amended claim 1 to recite “a build platform with a temperature control unit for regulating a temperature of the build platform” and “a polymer coating adjacent to a surface of the thermally conductive plate for maintaining adhesion between the 3D object and the build surface throughout the printing, which polymer coating has a surface that (i) facilitates adhesion to the 3D object during printing and (ii) permits removal of the 3D object once the 3D object has been formed and cooled by the temperature control unit, wherein the temperature control unit cools the 3D object subsequent to formation, to permit removal of the 3D object from the thermally conductive plate without removal of the thermally conductive plate from the build platform.” EX1002, at 77 (amendments to claim 1); *see also id.* at 76-86 (October 7, 2016 Response to Final Office Action). I have reproduced the amendments to claim 1 below.

Application No. 14/574,237
Response to Final Office Action filed October 7, 2016
Attorney Docket No. 50823-712.201

AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A build apparatus ~~working as a base for printing a 3D objects~~
~~object~~ of thermoplastics employing additive manufacturing methods, the apparatus comprising:

a build platform with a temperature control ~~[[means]]~~ unit for ~~heating-regulating a~~
~~temperature of~~ the build platform;

a ~~[[thin]]~~ thermally conductive ~~removable~~ plate ~~having a build surface meant to be~~
~~removably placed on top of~~ disposed adjacent to the build platform~~[[,]]~~; and

a polymer coating ~~coated over the~~ adjacent to a surface of the ~~removable-thermally~~
~~conductive~~ plate for maintaining adhesion between the 3D object and the build surface
throughout the printing, which polymer coating has a surface that (i) facilitates adhesion to the
3D object during printing and (ii) permits removal of the 3D object once the 3D object has been
formed and cooled by the temperature control unit.

wherein the temperature control unit cools the 3D object subsequent to formation, to
permit removal of the 3D object from the thermally conductive plate without removal of the
thermally conductive plate from the build platform; and

where the surface of the polymer coating is treated to improve adhesion between the 3D
object and the build surface.

73. According to the applicant, Comb did not teach or disclose all elements of claim 1, including “a build platform with a temperature control unit for regulating a temperature of the build platform . . . a polymer coating adjacent to a surface of the thermally conductive plate for maintaining adhesion between the 3D object and the build surface throughout the printing, which polymer coating has a surface that (i) facilitates adhesion to the 3D object during printing and (ii) permits removal of the 3D object once the 3D object has been formed and cooled by the temperature

control unit, wherein the temperature control unit cools the 3D object subsequent to formation, to permit removal of the 3D object from the thermally conductive plate without removal of the thermally conductive plate from the build platform.” *Id.* at 84.

74. Thereafter, I understand that the examiner conducted an interview with the applicant on October 27, 2016. EX1002, at 51. According to the interview summary, they discussed two prior art references, U.S. Patent Publication 2005/0058837 to *Farnworth* and U.S. Patent Publication 2013/0297320 to *Buser*, and the examiner’s proposed amendments. *Id.* The applicant and examiner “agreed on the content of the proposed amendments and the application is in condition for allowance.” *Id.*

75. After the interview, I understand that the examiner entered an amendment to the claims, as reproduced below.

AMENDMENT TO THE CLAIMS:

1. (Currently amended) A build apparatus for printing a 3D object of thermoplastics employing additive manufacturing methods, the apparatus comprising:

- a build platform with a temperature control unit ~~for regulating a temperature~~ configured to control heating of the build platform;
- a thermally conductive plate disposed adjacent to the build platform; and
- a polymer coating ~~adjacent~~ attached to a surface of the thermally conductive plate ~~for maintaining adhesion between the 3D object and the build surface throughout the printing, which polymer coating has a surface that~~ which is capable of (i) facilitates facilitating adhesion to the 3D object during printing and (ii) permits-permitting removal of the 3D object once the 3D object has been formed and cooled by the temperature control unit without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object, wherein the polymer coating is not a polymer tape;

~~wherein the temperature control unit cools the 3D object subsequent to formation, to permit removal of the 3D object from the thermally conductive plate without removal of the thermally conductive plate from the build platform.~~

Id. at 46; *see also id.* at 45-50 (Notice of Allowability). As shown, the examiner's amendment clarified that "a polymer coating attached to a surface of the thermally conductive plate which is capable of . . . (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object, wherein the polymer coating is not a polymer tape." *Id.* at 46.

76. The examiner also provided a statement of reasons for allowance. EX1002, at 49. According to the examiner, Comb, Buser, and Jacobs fail "to teach or suggest a polymer coating that is not a polymer tape attached to a surface of the

thermally conductive plate capable of (i) facilitating adhesion to the 3D object during printing and (ii) permitting removal of the 3D object once the 3D object has been formed and without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.” *Id.* As the examiner explained, “[t]his is considered to be novel because it solves critical issues in the current art (e.g. difficulty to remove the 3D object (P0005-0006 of instant PG-PUB), need of chemical/mechanical means to remove 3D object (P0028 of instant PG-PUB), or preventing damage to the polymer coating/3D object/plate (P0024 of instant PG-PUB)).” *Id.*

77. I note that the examiner had the Comb reference, which Petitioner included in the Petition, before them and considered the Comb reference in issuing the claims of the ’660 Patent. *See* EX1002, at 49.

VI. SUMMARY OF THE PRIOR ART

78. I have reviewed the references listed below, which I understand Petitioner has cited in support of Grounds 1A-2B of their Petition:

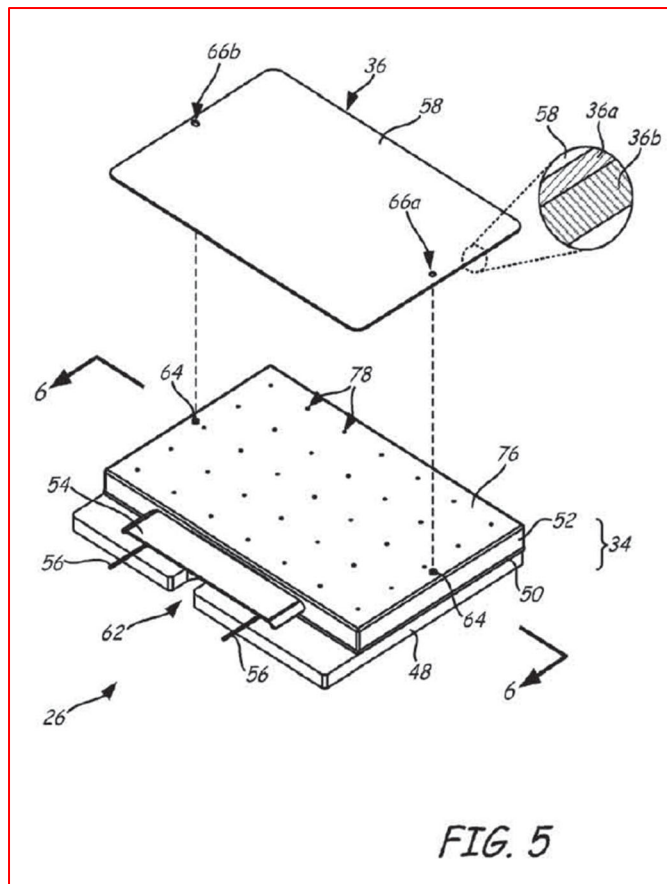
Ground	Claims	References Cited
1A	1–13, 15	Cable (US 2016/0075091) (EX1006) in view of Naware (US 2016/0096326) (EX1007)
1B	1–2, 4, 6–12, 15	Cable (EX1006) in view of Kritchman (US 2006/0054039) (EX1009)
1C	7–8, 14	Cable (EX1006) in view of Naware (EX1007) or

Ground	Claims	References Cited
		Kritchman (EX1009), and Comb (US 9,744,730) (EX1004)
2A	1–3, 5–15	Comb (EX1004) in view of Tummala (US 2013/0310507) (EX1005)
2B	1–15	Comb (EX1004) in view of Tummala (EX1005) and Kritchman (EX1009)

A. Overview of Comb (EX1004)

79. Comb (U.S. Patent No. 9,744,730) is directed to a magnetic platen assembly for use in an additive manufacturing system. EX1004, at Abstract, Title, 1:65-2:13. The platen assembly “includes a chuck portion and a plurality of build sheets.” *Id.* at 2:14-17; *see also id.* at 2:17-30. Comb also discloses a method for using a platen assembly in an additive manufacturing system. *See id.* at 2:31-47. The method includes “placing a first build sheet onto a top surface of a platen plate,” “printing layers of a 3D part onto the magnetically-coupled first build sheet,” “removing the first build sheet with the printed 3D part from the top surface of the platen plate,” and “placing a second build sheet onto the top surface of the platen plate.” *Id.*

80. As shown below, Figure 5 of Comb shows its build sheet removed from a chuck portion of the platen assembly. EX1004, Fig. 5, 3:31-33.



81. Comb shows that build sheet 36 has a top film 36a and base sheet 36b. *Id.* at 8:20-26. Comb explains that “[t]op film 36a may be derived from one or more polymeric coatings, tapes, or other lamina.” *Id.* at 8:27-29. Comb provides three examples of top film 36a. The first example is a “polycarbonate top film” that is “adhered with a high-temperature adhesive to a steel base sheet 36 b.” *Id.* at 8:29-33. The second example is “[f]or use with higher-temperature part materials, such as polyetherimide part materials” in which “top film 36a may be applied to base sheet 36b as a high-temperature tape, such as polyimide tapes commercially available under the trademark “KAPTON” from E. I. du Pont de Nemours and

Company, Wilmington, Del.” *Id.* at 8:34-39. And, the third example is “for use with lower temperature part materials, such as polylactic acid part materials” in which “tapes derived from polymeric materials having lower glass transition temperatures may be applied to base sheet 36 b.” *Id.* at 8:39-42.

B. Overview of Tummala (EX1005)

82. Tummala (U.S. Patent Publication No. 2013/0310507) is directed to an adhesive for 3D printing. EX1005, at Title. Tummala also discloses methods of printing a 3D article or object. *See id.* at [0010]. First, Tummala applies “an adhesive to a build surface of a print pad of a 3D printer.” *Id.* Second, Tummala “selectively depositing layers of a fluid ink or print material onto the surface of the print pad to form the 3D article.” *Id.* And third, Tummala “remov[es] the 3D article from the print pad.” *Id.* Thus, Tummala applies its adhesive “to a print pad prior to [the] beginning of a printing process” to deposit layers. *Id.* at ¶[0023]; *see also id.* at [0053] (“an adhesive described herein is a viscous gel at room temperature”), [0063] (“a method of printing a 3D article comprises applying an adhesive to a build surface of a print pad of a 3D printer”), [0064] (“a method described herein further comprises selectively depositing layers of a fluid ink or print material onto the build surface of the print pad to form the 3D article”). While Tummala’s adhesive is applied to a print pad at the start of each process for printing a 3D article or object, Tummala

explains that the print pad itself is reusable. *Id.* at ¶[0006] (“print pads are often reusable”).

83. Tummala also describes the components of its adhesive, which can include a first polymeric component, second polymeric component, solvent, surfactant, and preservative. *See* EX1005, at ¶[0028] (first polymeric), [0030]-[0033] (second polymeric), [0036]-[0037] (solvent), [0038]-[0040] (surfactant), [0041]-[0042] (preservative). Many of Tummala’s embodiments use an adhesive that includes polyvinyl alcohol or PVOH. *See id.* at Abstract (“In some embodiments, an adhesive for use with a 3D printer comprises a first polymeric component comprising a poly(vinyl alcohol) and a second polymeric component. The poly(vinyl alcohol), in some embodiments, comprises amorphous poly(vinyl alcohol). In some embodiments, the second polymeric component comprises a water-soluble polymer.”), [0028] (“In some embodiments wherein a first polymeric component does not necessarily comprise a PVOH, the first polymeric component comprises one or more of . . . poly(vinyl alcohol)”); *see also id.* at [0009], [0010], [0024], [0031], [0063].

84. Tummala states that its adhesive has a bonding strength between 2 and 50 times greater at 100° C than at room temperature. EX1005, at ¶[0047]. Similarly, Tummala’s adhesive has a bonding strength between 2 and 60 times greater when dry than when wet at 23° C. *Id.* at ¶[0048]. Accordingly, “in some embodiments,”

Tummala's adhesives "permit adhesion of a print material or printed part to a print pad throughout the print process until the part is complete" and permit "print materials and/or printed parts to be removed or peeled from the print pad easily, without breaking, and/or without the use of tools." *Id.* at ¶[0050]; *see also id.* at [0005] ("[A] strong bond can prevent the extruded print material from separating from the print pad prematurely but may also make it difficult to remove the printed 3D object and any support material from the print pad following completion of the print process. Further, this difficulty can require a user to employ a hand tool such as a scraper to separate the printed 3D object from the print pad, which can lead to damage to the printed 3D object and/or the surface of the print pad.").

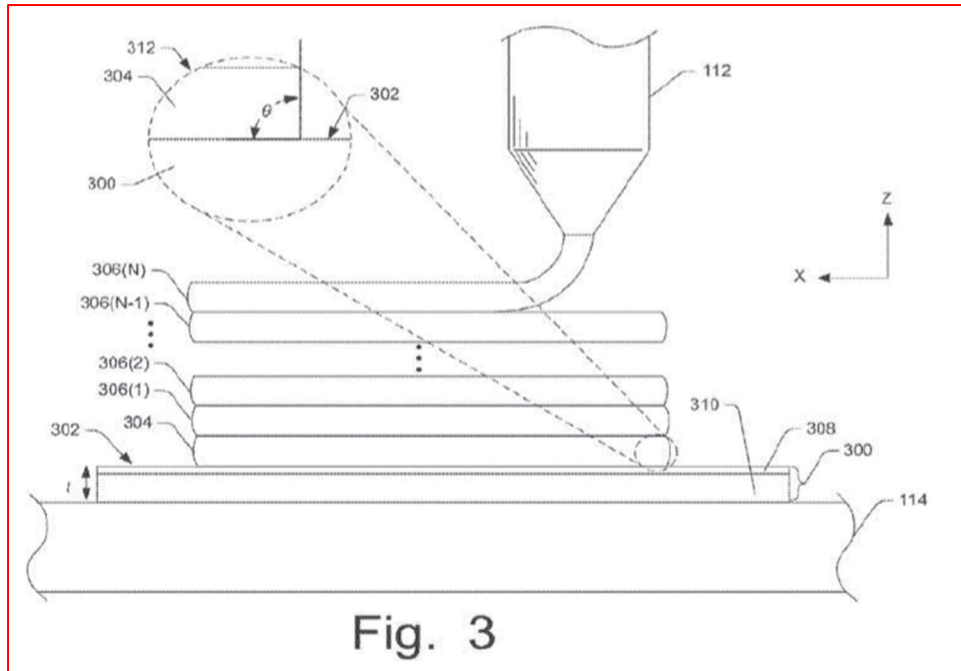
85. Against this background, Tummala explains that its adhesive "has adhesive properties that are tunable or selectable, so that the adhesive can act as both a bonding agent and a releasing agent." EX1005, at ¶[0046]. A bonding agent "bond[s] a print material or printed part to a print pad" and a releasing agent "facilitates release or separation of a print material or printed part from a print pad." *Id.* Tummala also provides Table I to show the properties of its adhesives as bonding and releasing agents. *See id.* As shown below in Table I, Tummala tested its adhesives on different footprints (2x2 and 3x3), raft configurations (raft and no raft), print pads (anodized aluminum and coarse grind textured glass), temperatures (100° C and 23° C), and dry/wet conditions.

TABLE I					
Footprint	Raft	Print Pad	100° C. (Dry)	23° C. (Dry)	23° C. (Wet)
2 × 2	raft	anodized aluminum	>20 lbs	0-0.5 lbs	0-0.5 lbs
2 × 2	no raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
2 × 2	no raft	Course Grind textured glass	—	>20 lbs	0-0.5 lbs
3 × 3	raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
3 × 3	no raft	anodized aluminum	>20 lbs	19 lbs	0-0.5 lbs

Id. at ¶[0046]. For each configuration of footprint, raft configuration, and print pad, Tummala provides the bonding strength under three different conditions (100° C, Dry; 23° C Dry, and 23° C Wet). *See id.* Tummala states that the “labels ‘Dry’ and ‘Wet’ refer to whether or not the print pad and part were submerged in water.” *Id.* Tummala also explains that for “entries in Table I below having an adhesion or bonding strength greater than 20 pounds, the parts broke before the parts separated from the print pad.” *Id.*

C. Overview of Cable (EX1006)

86. Cable (U.S. Patent Publication No. 2016/0075091) is directed to additive manufacturing object removal. EX1006, Title, Abstract. Figure 3 of Cable shows an additive manufacturing object with first layer 304 and multiple additional layers 306.



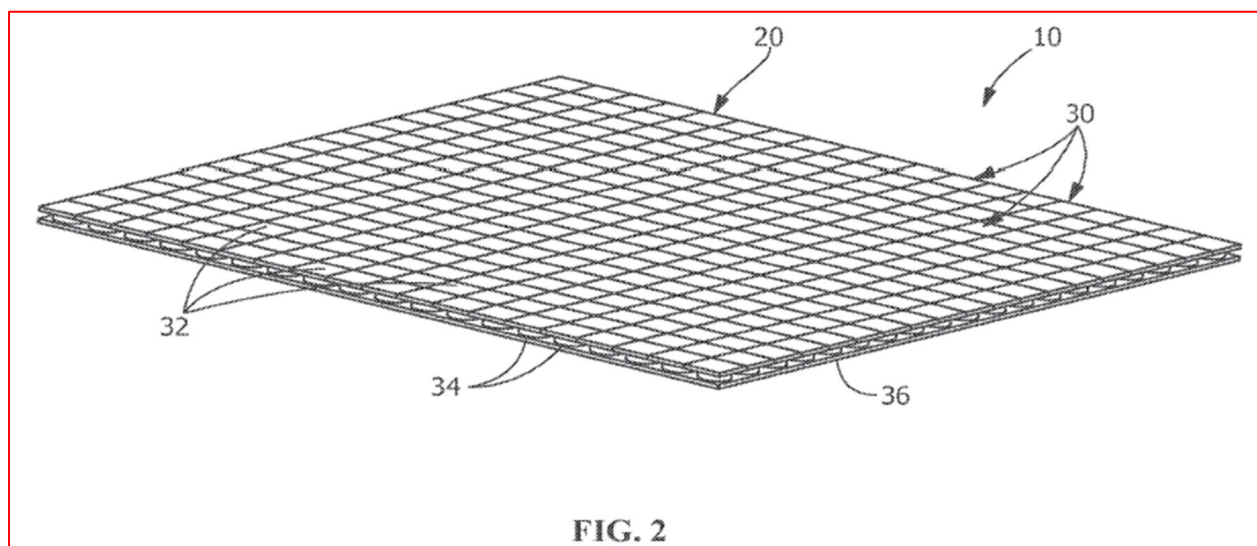
Id. at Fig. 3. A “a first layer 304 of build material is shown as being deposited directly onto the surface 302 of the substrate 300 according to a predetermined build path, which can represent a beginning of the additive manufacturing process.” *Id.* at ¶[0058]. “As the nozzle 112 moves at a predetermined speed according to a build pattern, multiple additional layers 306(1), 306(2), . . . , 306(N-1), 306(N) of the build material can be deposited in a layer-by-layer fashion to form the object 104 on the substrate 300.” *Id.* at ¶[0059]. “[T]he substrate 300 is shown as having at least a top layer 308 (‘surface layer 308’) that is made of a first material, such as any of the thermoplastic polymers described above.” *Id.* at ¶[0061]. Cable teaches two ways to make its substrate. “The substrate 300 shown in FIG. 3 can be manufactured by coating a main portion 310 or body of the substrate 300 with a first material (e.g., a thermoplastic polymer) to

form the top layer 308.” *Id.* “Alternatively, substantially all of the substrate 300 may be made of the first material, such as any of the thermoplastic polymers described above.” *Id.*

D. Overview of Naware (EX1007)

87. Naware (U.S. Patent Publication No. 2016/0096326) discloses a “selective zone temperature control build plate” that “includes multiple elements which have contact plates and temperature control modules.” EX1007, at Title, Abstract.

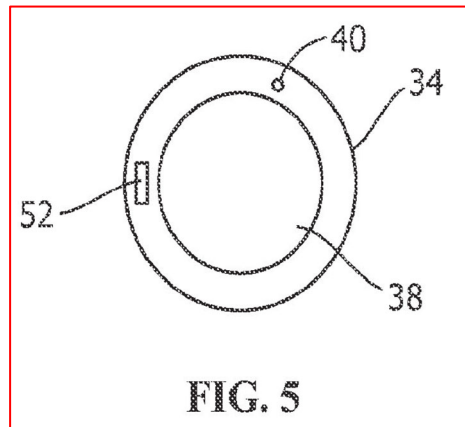
88. As shown below, Figure 2 of Naware shows its build plate 10 including “multiple numbers of zones of modular elements 30,” from 1 to N.



Id. at Fig. 2, [0031]. “Each modular element 30 consists of contact plate 32, temperature control module 34 and an insulating plate 36.” *Id.* “The plurality of

contact plates 32 of the multiple modular elements 30 form the upper surface 20, or at least a portion of the upper surface 20.” *Id.*

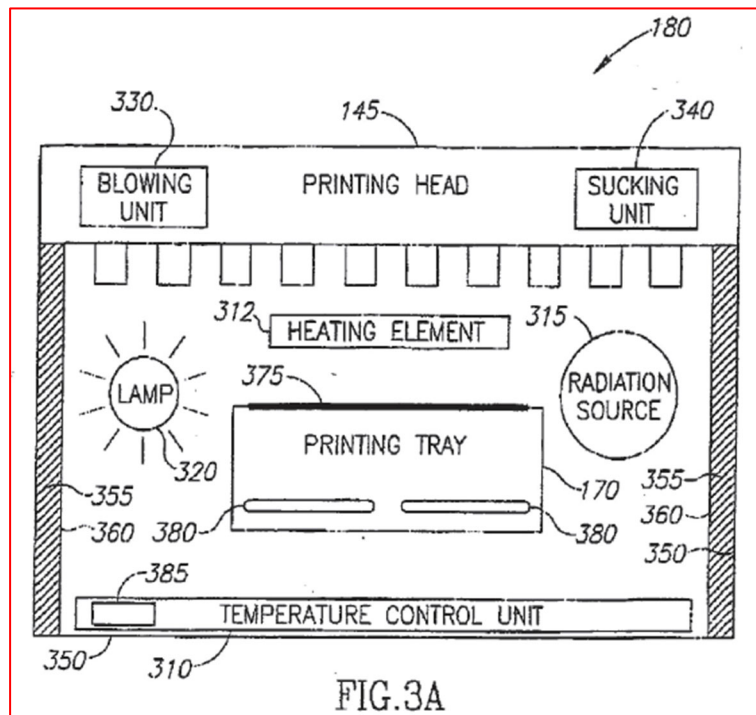
89. Figure 5 of Naware provides a cross-sectional view of one modular element.



EX1007 at Fig. 5. “Each temperature control module[] 34 is a device which has the ability to control the temperature thereof and consequently, control the temperature of its respective modular element 30.” *Id.* at ¶[0032]. “[T]he temperature control modules 34 include heating/cooling mechanisms 38 and temperature sensors 40.” *Id.* Naware explains that each of the temperature control modules 34 may be in communication with and is controlled by a microcontroller/processor 52 (FIG. 5), which in the illustrative embodiment shown is positioned proximate to or in the temperature control module.” *Id.* at ¶[0034]. “The heating/cooling mechanism 38 and the temperature sensor 40 may communicate with the microcontroller/processor 52 wirelessly or via fixed connections, such as, but not limited to, circuit paths or wires.” *Id.*

E. Overview of Kritchman (EX1009)

90. Kritchman (U.S. Patent Publication No. 2006/0054039) is directed to a process of and apparatus for three-dimensional printing. EX1009 at Title, Abstract. Kritchman shows a schematic illustration of its printing sub-system 180 or printing cell in Figure 3A, which I reproduce below.



Id. at Fig. 3A, [0099]. “Printing sub-system 180 may include, for example, a blowing unit 330 and and/or a sucking unit 340, for respectively cooling of printing sub-system 180 by sucking hot air or other substances out of printing sub-system 180 and/or drawing cool air or other substances in to printing sub-system 180 from the surroundings.” *Id.* In addition, “[p]rinting sub-system 180 may include a temperature control unit 310 and/or Temperature control unit 310 may

include a heating source and/or a cooling source.” *Id.* Further, “[p]rinting sub-system 180 may include a temperature sensing unit 385, optionally associated with temperature control unit 310, to sense the temperature of cell 180, tray 170, building, materials etc.” *Id.* An electromagnetic radiation source 315 can “enable heating of the building material before, during, and/or after deposition,” and an electromagnetic lamp 320 is “for curing and/or warming of printed objects,” and heating element 312 for “warming the upper layers” of the building material. *Id.* at ¶¶[0099], [0101].

VII. GROUND 1A: CLAIMS 1–13, 15 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 1A (COMBINATION OF CABLE AND NAWARE)

91. In Ground 1A of the Petition, Petitioner asserts that claims 1–13 and 15 are obvious over the combination of Cable and Naware. *See* Petition at 8-10 (Overview of Cable), 11 (Overview of Naware), 12-15 (Asserted Motivation to Combine), 15 (Asserted Reasonable Expectation of Success), 16-17 (1.pre), 17-19 (1.a), 20-21 (1.b), 21-22 (1.c), 23 (1.c.i), 23-25 (1.c.ii), 25-26 (1.c.iii), 26-27 (claim 2), 27-29 (claim 3), 29-30 (claim 4), 30 (claim 5), 31-32 (claim 6), 32-33 (claim 7), 33 (claim 8), 33-34 (claim 9), 34-35 (claim 10), 35 (claim 11), 36 (claims 12, 13, and 15).

92. I have reviewed Petitioner’s challenges in Ground 1A, and it is my opinion that Ground 1A fails to teach or suggest all elements of claims 1–13, and 15. I explain my opinions below in detail.

A. Claim 1, Element 1.c.ii

93. Claim 1 of the '660 Patent requires, among other elements, “a polymer coating . . . which is capable of . . . (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.” EX1001, at 6:39-46; *supra* Section II (“The Challenged Claims of the '660 Patent”), Claim Element 1.c.ii.

94. I understand that Petitioner contends that Cable teaches this claim element. *See* Petition, at 23-25. Petitioner asserts that the object is removed from the substrate by flexing the substrate so that the object can pop off. *See id.* at 23 (citing EX1006 (Cable), [0052], [0023], [0067], [0079], Figures 1-6, [0044]; EX1002 (Decl. of Dr. Hickner), ¶¶89-90). Petitioner also asserts that “Cable makes clear that the object is removed from the polymer-coated substrate without chemically or mechanically removing the polymer coating from 3D object.” *See* Petition at 24 (citing EX1006 (Cable), [0052], [0004], [0006], [0020], [0023], [0067], [0068–0078], [0036], [0061], [0080], Figures 5–6). Further, Petitioner asserts that there is “no need to chemically or mechanically remove the coating from the 3D object, because the coating remains behind.” *See* Petition at 24-25 (citing EX1006 (Cable), [0052], Fig. 6; EX1003 (Decl. of Dr. Hickner), ¶¶91-92).

95. It is my opinion that Cable in the Cable-Naware combination teaches that there is damage to the polymer coating and 3D object upon removal and that the polymer coating is chemically or mechanically removed from the 3D object. Cable generally states that an object can be removed from the substrate “with minimal or no damage” to the object and substrate, such that no residue “that is visible to the eye” is left on the substrate. EX1006, [0052] (“By forming the object 104 on the substrate 110 as described with respect to implementations described herein, the object 104 can be removed from the substrate 110 with minimal or no damage to the object 104 and to the substrate 110.”), [0082] (“In this manner, the object 104 can be removed from the substrate 110 with minimal, if any, damage to the substrate 110 and/or the object 104 and the substrate 110 can be re-used.”), [0067] (“With optimal adhesion characteristics, the object 104 can delaminate from the substrate 110 without leaving a residue that is visible to the eye.”). Cable also generally discloses that a polymeric sheet can be between 0.7 and 3 millimeters thick to be flexed for dislodging a complete object from the sheet. *See* EX1006, ¶[0006] (“the sheet may be a polymeric sheet having a thickness included within a range of about 0.7 mm to about 3 mm”). However, as I discuss below, a POSITA would have understood that Cable does not disclose how removal of an object can be achieved without leaving behind a portion of the damaged object as residue that is visible to the eye. In

addition, a POSITA would have recognized that extensive experimentation would have been required to determine if any solution can satisfy these general statements.

96. Cable teaches that its substrate is configured “to elastically deform in response to a load applied to the sheet causing a deflection at a center of the sheet in an amount of at least about 12 mm.” EX1006, at Abstract; *see also id.* at [0006] (“One item included in the package may be a sheet configured to elastically deform in response to a load applied to the sheet causing a deflection at a center of the sheet in an amount of at least about 12 millimeters (mm) and/or causing a radius of curvature of the sheet to be less than or equal to about 305 mm.”). Cable explains that “in order to cause the object 104 to be dislodged from the substrate 110,” the substrate is “configured to flex in three-point bending with a center deflection, d , of at least about 12 mm.” *Id.* at [0071]. However, Cable also recognizes that the substrate must have flexural strength. *See id.* at [0071] (“Moreover, since the substrate 110 is to be reused for repeatedly forming objects 104 thereon, the flexural strength, R , of the substrate 110 can be selected to be of an amount where the maximum applied load, P_{max} , at the point of fracture (or plastic deformation for materials that deform plastically before fracture) of the substrate 110, is greater than the load, P , on the substrate 110 causing the center deflection, d , of at least about 12 mm. The condition of P being less than P_{max} in this scenario means that the substrate 110 can deform elastically to achieve the center deflection, d .”); *see also*

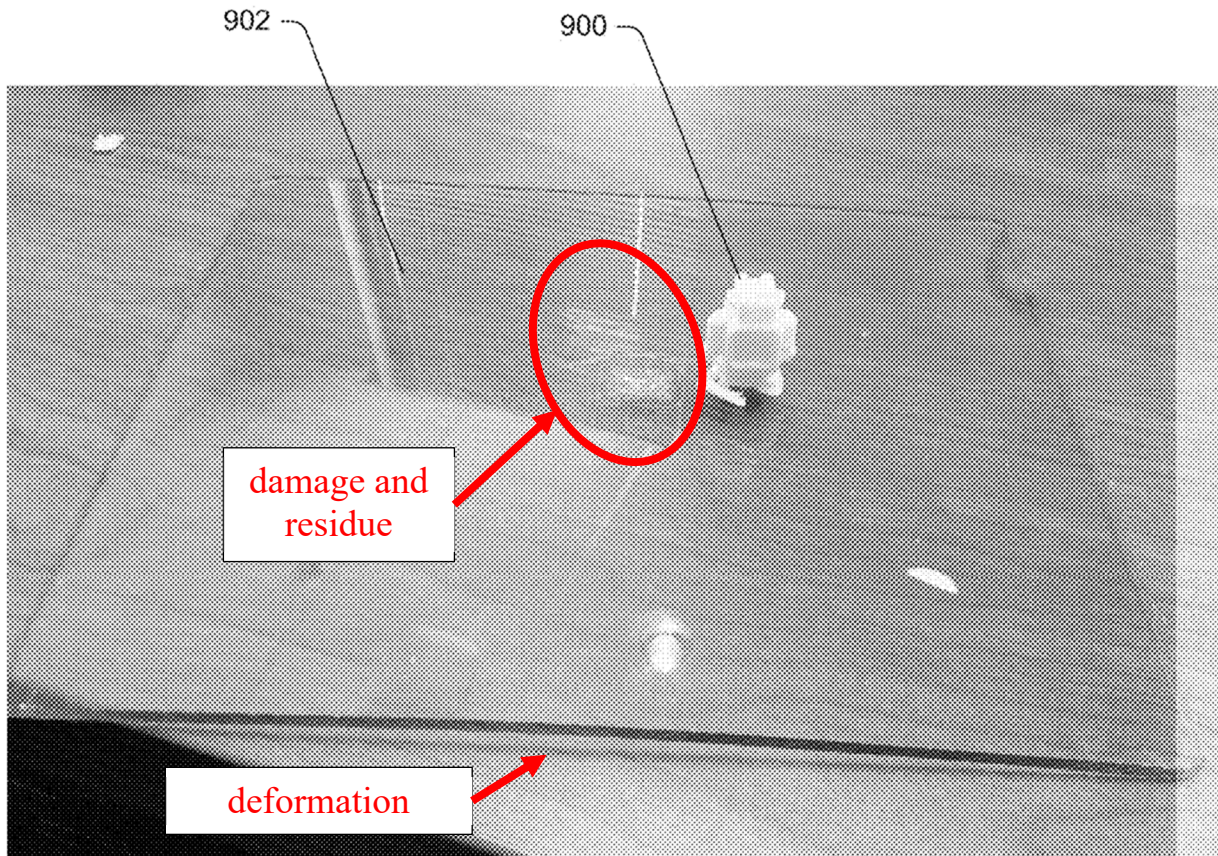
id. at [0072]. Accordingly, Cable places important restrictions on its substrate to deflect by about 12 millimeters and yet avoid deformation or fracture.

97. Cable recognizes that many substrates cannot be sufficiently deflected by flexing or bending the substrate to remove an object. Example 2 in Cable, which Petitioner and its expert, Dr. Hickner, did not expressly consider, unsuccessfully used “substrate 902 [that] was formed from a Tritan TX1000 copolyester” with a thickness of “about 4 mm.” EX1006, at [0086]. As I discuss below, due to a deformed substrate with damage and residue from the printed object, a POSITA would have understood that such a substrate does not permit removal of the 3D object without mechanically or chemically removing the polymer coating from the 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.

98. As Cable explains, “[a]fter forming the object 900 on the substrate 902, an attempt was made to remove the object 900 from the substrate 902 by an individual flexing two edges of the substrate 902 with their hands, but the object 900 was not released from the substrate 902.” *Id.* Because flexing substrate 902 was unsuccessful, Cable teaches that “object 900 was removed from the substrate 902 using a blade (i.e., mechanically contacting the object 900).” *Id.* In short, Cable teaches that “substrate 902 was too thick to flex” sufficiently “to cause removal of

the object 900 from the substrate 902 without mechanically contacting the object 900.” *Id.*

99. Figure 9 of Cable shows the substrate and object of Example 2.



Id. at Fig. 9 (annotated). Figure 9 shows object 900 was removed from substrate 902. In addition, the top surface of substrate 902 shows damage and residue to the left of object 900. The location of the damage and residue likely corresponds to the location where object 900 was originally printed or fabricated. A POSITA would have understood that the damage corresponds to the removal of object 900 by using a

blade, resulting in scratch marks on the top surface of the substrate. I note that the scratch marks appear to be much larger than the surface area of object 900.

100. A POSITA would also have understood that the lower right side of the encircled region shows that the surface of substrate 902 has visible residue from object 900. The residue represents a visible portion of object 900 that was not properly separated from substrate 902 when removing object 900. Thus, for the substrate 902 to be re-used, the polymer coating (surface of substrate 902) must be removed from this portion of object 900 mechanically or chemically. As shown in Figure 9 above, such removal (chemical or mechanical) also damages the polymer coating on the surface of the substrate. *See* EX1006, Fig. 9. Thus, the polymer coating is chemically or mechanically removed from the 3D object and the polymer coating is damaged.

101. In addition, a POSITA would have understood from Figure 9 of Cable that there is plastic deformation in substrate 902 that was likely caused when flexing the substrate by hand. As a result, a POSITA would have understood that substrate 902 is no longer flat and cannot ordinarily be reused for three-dimensional printing. As Cable explains, plastic materials, such as substrate 902, deform “before fracture” when placed under a load that is greater than the maximum load under which the material can deform elastically. *See* EX1006, ¶[0071] (“Moreover, since the substrate 110 is to be reused for repeatedly forming objects 104 thereon, the flexural

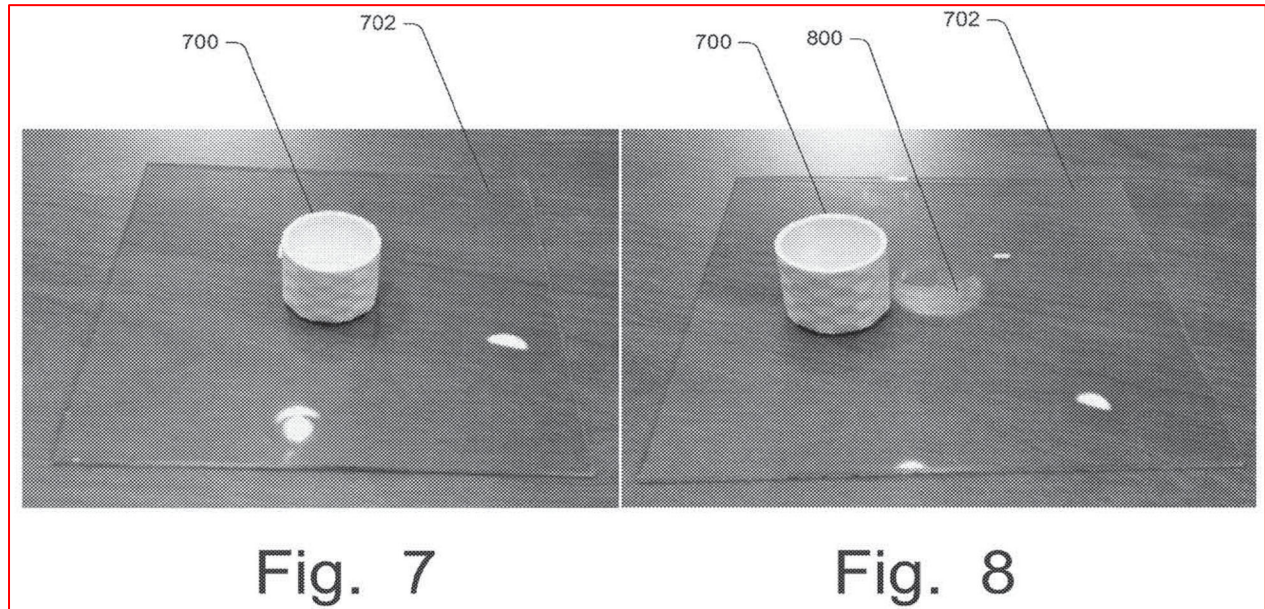
strength, R , of the substrate 110 can be selected to be of an amount where the maximum applied load, P_{max} , at the point of fracture (or plastic deformation for materials that deform plastically before fracture) of the substrate 110, is greater than the load, P , on the substrate 110 causing the center deflection, d , of at least about 12 mm. The condition of P being less than P_{max} in this scenario means that the substrate 110 can deform elastically to achieve the center deflection, d .”). Thus, a POSITA would have recognized that such a substrate does not permit removal of the 3D object without damaging the polymer coating and plate.

102. As I discussed above, Example 2 and corresponding Figure 9 of Cable show that the object cannot be removed without damaging the object and substrate and that visible residue of the object is left on the substrate and thus the substrate must be mechanically or chemically removed from the residue. As I discuss below, Cable teaches substrates with damage and residue from the printed object, and thus a POSITA would have understood that Cable does not disclose to a POSITA how an object can be removed from a substrate without visible residue and thus no damage to the object or substrate.

103. Example 1 of Cable describes an object 700 that leaves behind visible residue when being removed from a substrate (702). EX1006, ¶[0085]. The substrate in Example 1 “was formed from a Tritan TX1000 copolyester” and was “about 2mm” thick. *Id.* Although Cable claims that “object 700 was not damaged after the

removal from substrate 702 and a minimum amount of residue 800 remained on the substrate 702 after the removal of the object 700,” a POSITA would have understood that residue 800 represents a visible portion of object 700 that was not properly removed from substrate 702. Thus, the polymer coating (surface of substrate 702) must be removed from this portion of object 900 mechanically or chemically.

104. As shown in Figures 7 and 8 below, the residue (800) is clearly visible in Figure 8 at a location corresponding to the location of object 700 in Figure 7.

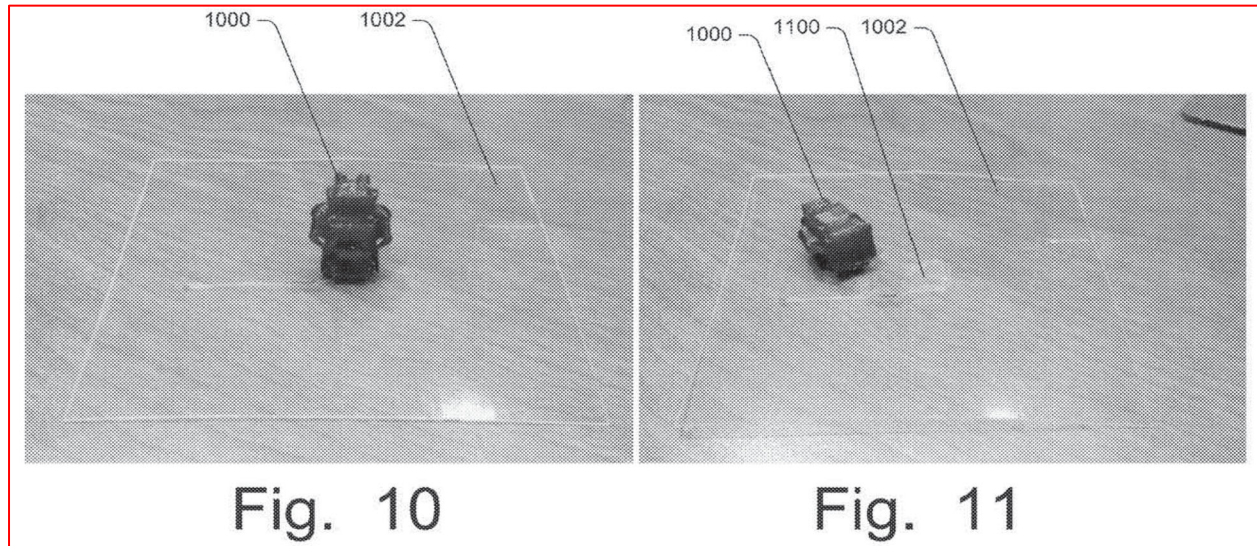


Id. at Figs. 7-8. Additionally, the residue 800 has a similar circular shape as the shape of object 700. A POSITA would have understood that object 700 is damaged because a visible portion of the object (700) was not properly removed from the surface of substrate 702. A POSITA would also have understood that the surface of substrate 702 is damaged because there is a visible portion of object (700) that remains. A

POSITA would have recognized that in order to use the substrate again it would have needed to chemically or mechanically remove the surface of the substrate (702) from a visible portion of object 700, shown as residue 800. *See* EX1006, [0024] (“a tool, such as a chisel or knife, or a chemical process may be used to remove an object from the substrate that cause unwanted damage (e.g., removal of portions of the object, removal of portions of the substrate, etc.)”). As shown in Figure 9 of Cable (reproduced above), a POSITA would have recognized that such chemical or mechanical removal also risks damage to the polymer coating. *See* EX1006, Fig. 9, [0086].

105. Similarly, Example 3 of Cable describes an object (1000) that leaves behind visible residue (1100) when removed from a substrate (1002). EX1006, ¶[0087]. The substrate in Example 3 “was formed from a Tritan TX1000 copolyester” and was “about 0.76 mm” thick. *Id.* Although Cable claims that “object 1000 was not damaged after the removal from the substrate 1002 and a minimum amount of residue remained 1100 on the substrate 1002 after the removal of the object 1000,” a POSITA would have understood that residue 1100 represents a visible portion of object 1000 that was not properly removed from substrate 1002. Thus, the polymer coating (surface of substrate 1002) must be removed from this portion of object 900 mechanically or chemically.

106. As shown in Figures 10 and 11 below, the residue (1100) is clearly visible in Figure 11 at a location corresponding to the location of the object (1000) in Figure 10.



Id. at Figs. 10-11. Additionally, the residue (1100) has a similar shape as the base of object 1100. A POSITA would have understood that object 1000 is damaged because a visible portion of the object 1000 was not properly removed from the surface of substrate 1002. A POSITA would also have understood that the surface of substrate 1002 is damaged because there is a visible portion of object (1000) that remains. A POSITA would have recognized that in order to use the substrate again it would have needed to chemically or mechanically remove the surface of the substrate (1002) from a portion of the object 1000, shown as residue 1100. *See* EX1006, at [0024] (“a tool, such as a chisel or knife, or a chemical process may be used to remove an object from the substrate that cause unwanted damage (e.g., removal of portions of the

object, removal of portions of the substrate, etc.)”). As shown in Figure 9 of Cable (reproduced above), a POSITA would have recognized that such chemical or mechanical removal also risks damage to the polymer coating. *See* EX1006, Fig. 9, [0086]. Despite Cable providing an explanation of how to apparently configure its substrate for resilient flexing or bending to remove an object without damage (*see* EX1006, at ¶¶[0068]–[0078]), when considering Cable’s disclosure as a whole it does not teach removing the object without leaving behind a visible portion of the object as residue on the substrate. In particular, a POSITA would have understood that the object is damaged because a visible portion of it was not properly removed from the surface of the substrate, that the surface of the substrate is damaged because there is a visible portion of object that remains, and that in order to use the substrate again a POSITA would have needed to chemically or mechanically remove the surface of the substrate from the visible portion of the object. Thus, the combination does not teach “a polymer coating which is capable of . . . (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.” EX1001, at 6:39-46; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim Element 1.c.ii.

107. Further, based on Cable’s full disclosure, a POSITA would have understood that extensive experimentation would have been required even when following Cable’s teachings for configuring the substrate to determine if any solution could support object removal without damage such that no visible residue is left behind. Indeed, Cable recognizes the unpredictable nature of its teachings. Cable provides “Comparable Example 1” with a 10mm thick substrate of glass in which “the base of the partially completed object became detached from the substrate.” EX1006, at ¶[0088]. As Cable recognizes, there may be multiple theories for this failure. *See id.* (“Without being tied to any particular theory”). Cable proceeds to speculate that the failure might have been related to “the differences between the physical characteristics of the substrate and the material of the object” and “lack of heating of the 3D printer platform.” *Id.* A POSITA would have recognized that it would have needed to experiment based on Cable’s teachings about surface energies (*see* EX1006, [0063]-[0064]), Hildebrand solubility parameters (*see id.*, [0064], [0067]), and deflection, stiffness, and strength (*see id.* at [0068]-[0072]), to identify possible materials for the first layer of the object, surface of the substrate, and substrate, possible sizes of those materials, and other conditions, such as the temperatures applied to build material at various stages of extrusion. *See also id.* at [0031] (“The temperature applied to the material in the extrusion head 108 can vary depending on the material being heated.”), [0033] (“Additionally, the

temperature applied to heat the material in the extrusion head 108 can be based on a glass transition temperature of the material.”), [0044] (“The object 104 can be formed in a controlled environment, such as by confining individual ones of the components of the system 100 (e.g., the substrate 110, the extrusion head 108 and the nozzle 112, etc.) to a chamber or other enclosure where temperature, and perhaps other parameters (e.g., pressure) can be controlled and maintained at a desired level by elements configured to control temperature, pressure, etc. (e.g., heating elements, pumps, etc.). In some instances, the temperature applied to the build material can correspond to a temperature at or above the creep-relaxation temperature of the build material. This can allow more gradual cooling of the build material as it is deposited onto the substrate 110 so as to prevent warping of the layers of the object 104 upon deposition. On the other hand, an environment that is maintained at a temperature that is too high for a given build material can cause the build material formed on the substrate 110 to droop before it is solidified in the object 104, potentially causing distortions in the final shape of the object 104.”), [0045] (“Additionally, the platform 114 can be heated.”); EX1001, at 4:3-7 (“heating of the plate produces rippling, bowing, or warping of the plate, resulting in a print surface that is uneven or not consistently level.”). Moreover, Cable teaches that there are multiple, speculative theories for why the solution will not work. *See, e.g.*, EX1006 at [0088]. As such, a POSITA would have needed to construct working examples according to identified

solutions and run experiments, as Cable did. *See* EX1006, [0085]-[0088], Figs. 7-11. But as Cable's experiments show and as I discussed above, none of the working examples were able to support object removal without damage such that no visible residue is left behind. *See id.* Given this unpredictability, a POSITA would have needed to run extensive experiments to identify many possible solutions and determine if any of them were able to support object removal without such damage. Thus, Cable does not have an enabling disclosure sufficient to allow a POSITA to practice claim 1 of the '660 Patent without undue experimentation. *Supra* Section IV.B (Legal Standard for Prior Art).

108. Thus, there is no teaching in the Cable-Naware combination of "a polymer coating which is capable of . . . (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object." EX1001, at 6:39-46; *supra* Section II ("The Challenged Claims of the '660 Patent"), Claim Element 1.c.ii.

B. Claim 1, Element 1.c.iii

109. Claim 1 of the '660 Patent also requires, among other elements, "wherein the polymer coating is not a polymer tape." EX1001, at 6:45-47; *supra* Section II ("The Challenged Claims of the '660 Patent"), Claim Element 1.c.iii.

110. I understand that Petitioner contends that Cable teaches a non-tape polymer coating. *See* Petition, at 25-26 (citing EX1006, at [0002], [0078]; EX1003, ¶¶93-98, 37-44; EX1001, at 1:31-64, 4:35-38).

111. As an initial matter, I disagree with Petitioner’s assertion that the use of the term “coating” connotes a structure that is not tape. *See* Pet. at 25-26 (citing EX1006, at [0002]; EX1003, at ¶¶93-95, 37-39, 44). In my opinion, a POSITA would have understood that a coating can commonly refer to a tape that is used in the process of making a coated surface. The ’660 Patent recognizes that polyimide tape is a coating that may be damaged “under high temperatures” in which its adhesive “can burn off.” EX1001, at 1:54-56. In relation to three-dimensional printing, comparison between the performance of uncoated surfaces to the performance of surfaces coated with tape was common. *See* EX1011 at 269 (“some have had success with printing PLA on clean, uncoated heated glass or using hardware store–variety blue painter’s tape with both PLA and ABS”). Additionally, a POSITA would have recognized that polymer tapes were also used as coatings in other fields, such as making coated pipes using polymer tapes. In fact, by 1976, it was known that “[t]he use of coatings applied in the form of tape is also increasing.” EX2017, at 14. It was also known that tapes were used as a laminate. *See id.* at 22 (Laminated tapes).

112. Further, I disagree with Petitioner’s assertion that Cable expressly distinguishes his embodiments from known solutions like “painter’s tape.” *See* Petition, at 26 (citing EX1006, at [0002]). Cable recognizes several known solutions for substrate surfaces, including “painter’s tape, glass, garolite, [and] fiberglass.” EX1006, at [0002]. While Cable describes the possible disadvantages of glass (*id.* at [0088]), Cable does not discourage use of these known solutions for substrate surfaces. *See also* EX1011 at 269 (recognizing that some have had success with printing PLA and ABS on blue painter’s tape). Instead, a POSITA would have understood that Cable describes a method of three-dimensional object removal that selects various materials and material sizes. For example, the first material of the substrate and material of the first layer of the object may be selected according to surface energies and Hildebrand solubility parameters. *See* EX1006, at [0062]–[0078]. A POSITA would have recognized that the known solutions for substrate surfaces, such as blue painter’s tape, would have been used if the corresponding material is selected according to Cable’s teachings.

113. Unlike Cable’s teachings about a method that selects various materials and material sizes without discouraging the use of known solutions, the ’660 Patent repeatedly distinguishes its polymer coating from polyimide tape coatings. *Supra* Section VI.A (Summary of the ’660 Patent). For example, unlike polyimide tape coatings that were “scratched or punctured” easily, needed replacement after builds

with high build platform temperatures, and trapped debris or air bubbles resulting in an uneven surface, the polymer coating of the '660 Patent does not wear away when used at high temperatures and provides an even surface for three-dimensional printing. *See, e.g.*, EX1001, 6:7-21, 4:34-35, 4:55-58.

114. While Cable describes a substrate made by coating a main portion or body, Cable does not teach or suggest a non-tape coating to a POSITA. *See* EX1006, [0061], [0036], [0080]. As I explained above, coatings can commonly refer to tapes. In addition, a POSITA would have understood that tapes were commonly used in multiple layers to provide a “laminar arrangement.” *See* EX1006 (Cable), at [0078] (“the substrate 300 may be comprised of any number of different materials in any suitable laminar arrangement”). The '660 Patent recognizes a laminar arrangement in which “the bottom layer of tape can permanently adhere to the 3D part.” EX1001, at 1:59-62. In the field of three-dimensional printing, it was common to use Kapton tape in laminar arrangements with a “sheet of aluminum or glass” that is “ideally layered with Kapton tape.” EX1011, at 269. Further, it was known in other fields that tapes were used as laminates. EX2017, at 22 (Laminated tapes).

115. Further, I disagree with Petitioner and its expert, Dr. Hickner, who argue that it would have been obvious to pursue a non-tape solution for implementing Cable’s polymer coating. In particular, Petitioner and Dr. Hickner have not shown that the “difficulties/drawbacks of polymer tapes like Kapton tape

were well documented.” Petition, at 26 (citing EX1003, at ¶¶96, 40-43). Indeed, Dr. Hickner relies on a reference (Exhibit 1011) that offers a “nifty way” to apply polyimide tape even though ordinary solutions for polyimide tape “can be a little tricky.” EX1011, at 283 (cited by EX1003, at ¶39). The same reference explains that printed surfaces are often covered in tape (such as Kapton or polyimide tape) “that is inexpensive to replace periodically.” EX1011 at 10. Contrary to Petitioner’s conclusion, these teachings show that polymer tapes had well-known advantages, which would have led a POSITA to use polymer tapes to coat Cable’s substrate for three-dimensional printing.

116. Thus, there is no teaching in the Cable-Naware combination of “wherein the polymer coating is not a polymer tape.” EX1001, at 6:45-47; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim Element 1.c.iii.

C. Claim 4

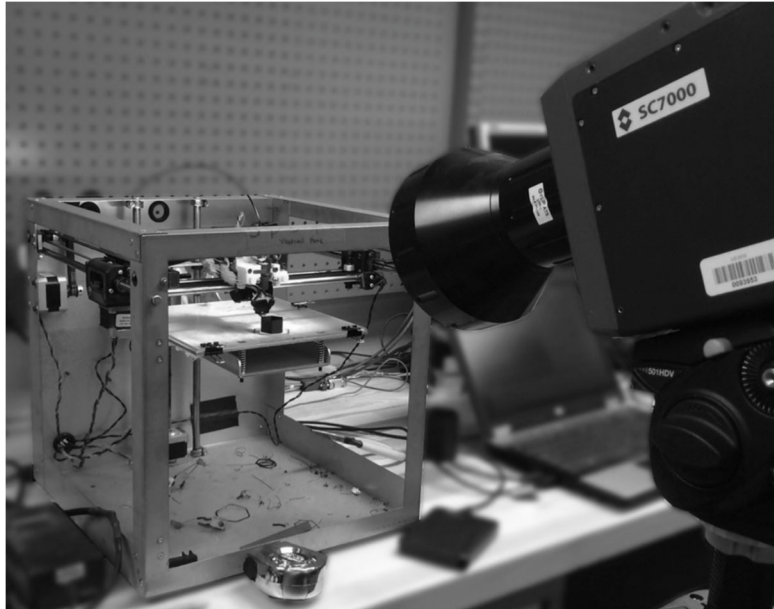
117. Claim 4 of the ’660 Patent recites the “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.” EX1001, 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

118. I understand that Petitioner asserts that Naware teaches the use of thermocouples in the combination as one of a finite number of interchangeable

solutions for measuring surface temperature. Petition, at 29 (citing EX1003, at ¶106).

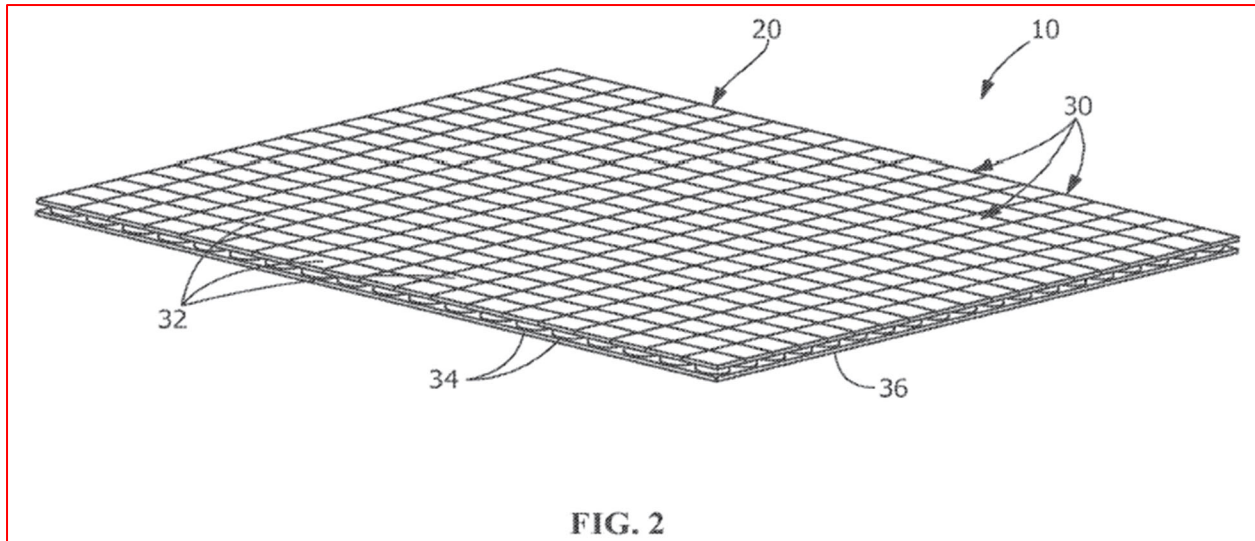
119. In my opinion, it would not have been obvious to a POSITA to try thermocouples with Naware's design. Dr. Hickner only recognizes two options: thermocouples and thermistors. *See id.* However, a POSITA would have understood that there are thousands of options for measuring surface temperature. For example, resistance temperature detectors (RTDs) could have been used for accurate temperature readings (e.g., 0.06% tolerance). EX2011 at 1-2. A common electronics supplier, Digi-Key, offered 129 different RTDs for sale in 2016. *See id.* While this reference (EX2011) is from 2016, its contents reflect that many types of RTDs were commonly available by 2014. As another example, semiconductor-based temperature sensors could have been used to provide reasonably accurate options for measuring temperature (e.g., 0.2 °C accuracy). EX2012 at 1-3. Digi-Key offered 1,212 solid state temperature sensors for sale in 2016 and 3,513 temperature sensors with both analog and digital output for temperatures up to around 125 °C. EX2012 at 1; EX2013 at 1. While these references (EX2012 and EX2013) are from 2016 and 2017, their contents reflect that many types of semiconductor-based temperature sensors were commonly available by 2014. As further examples, a POSITA would have recognized that non-contact temperature sensors, such as infrared imaging devices, could have been particularly beneficial in Naware's modular, matrix design

with many temperature control zones. Numerous examples of infrared imaging devices for detailed temperature measurements across a surface could have been used in Naware's design. *See, e.g.* EX2015, EX2016. For example, a mid-wave IR camera could have been used with a field of view of 15.5 $\mu\text{m}/\text{pixel}$:



EX2015 at 3. As another example, a two-color infrared thermometer could have been used with a response time of just 10ms. *See* EX2016, at 1-2. Accordingly, thermocouples are not simply one of a finite set of solutions for measuring surface temperature.

120. Further, there is no motivation to try using hundreds (if not more) thermocouples in each temperature control modules of Naware's matrix solution.



EX1007, at Fig. 2. A POSITA would have recognized that thermocouples are typically used for much higher temperatures than a heated build plate, such as for an extruder. *See* EX1014 at 4 (“switched from thermistors to thermocouples for temperature measurement on the extruder”). A POSITA would have also recognized that other forms of temperature measurement, such as an infrared camera, would have been used with Naware’s matrix arrangement of hundreds of temperature control modules. *See, e.g.,* EX2015, EX2016.

121. Thus, there is no teaching in the Cable-Naware combination of a “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.” EX1001, at 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

D. Claim 7

122. Claim 7 of the '660 Patent recites the “build apparatus of claim 1, wherein the material for the thermally conductive plate comprises one or more of aluminum, steel, brass, ceramic, glass, or alloys with a low coefficient of thermal expansion (CTE).” EX1001, 6:64-67; *supra* Section II (“The Challenged Claims of the '660 Patent”), Claim 7.

123. I understand that Petitioner has asserted that Cable teaches a substrate that is aluminum or steel. *See* Petition, at 32 (citing EX1003, at ¶114).

124. In my opinion, Cable does not teach the use of aluminum or steel under its teachings to substantially bend or flex the substrate to remove the printed object without deforming the substrate. As Cable explains, the substrate’s material must be able to “bend or flex resiliently” by about 12 millimeters. EX1006, at [0077]; *see also id.* [0068]-[0072], Abstract, [0006]. Accordingly, Cable provides three examples that use Tritan TX1000 copolyester substrates that are around 4, 2, and 0.76 millimeters in thickness. *See id.*, at [0085]-[0087], Figs. 7-11. Cable also teaches that the 4-millimeter-thick copolyester substrate cannot bend or flex resiliently. *See id.*

125. In my view, Petitioner and Dr. Hickner have failed to show that Cable’s solution would have worked for a thin plate of steel or aluminum. Equation 2 of

Cable explains how to calculate the area moment of inertia, I , which equals b times t^3 divided by 12.

$$I = \frac{1}{12}bt^3 \quad \text{Eq. (2)}$$

Id. at [0068]. As Cable explains, a thicker substrate (t) will cause the substrate “to be stiffer in bending when subjected to the flexing shown in FIG. 5.” *Id.* at [0069].

126. In addition to the thickness of the material, the modulus of elasticity or Young’s modulus (E) provides the amount of deflection (d) of the material under load, as specified by Equation 3 in Cable:

$$d = \frac{PL^3}{48EI} \quad \text{Eq. (3)}$$

Id. at [0069]-[0070]. As I mentioned earlier, Cable teaches that the substrate is configured to flex or deflect around 12 millimeters. *See id.* at [0071] (“in order to cause the object 104 to be dislodged from the substrate 110,” the substrate is “configured to flex in three-point bending with a center deflection, d , of at least about 12 mm”).

127. Cable also teaches that the flexural strength of the material must be less than the load on the substrate when causing center deflection by about 12

millimeters. Accordingly, Cable provides equation (4) to calculate the flexural strength or maximum applied load.

$$R = \frac{3P_{\max} * L}{2br^2} \quad \text{Eq. (4)}$$

Id. at [0071]. As I discussed above, the substrate in Example 2 of Cable, as shown in Figure 9, shows plastic deformation rather than elastic deformation, indicating that the load applied exceeded the maximum load of the material. *See id.* at Fig. 9.

128. Although Cable discloses that metals can generally bend or flex resiliently, Cable does not teach which metals work for this purpose or whether any particular metal can bend or flex resiliently by 12 millimeters, sufficient to remove an object. Petitioner and Dr. Hickner have not analyzed whether aluminum or steel would have worked under all of the conditions imposed by Cable's teachings. For example, a POSITA would have understood that thicker plates of aluminum or steel are difficult to flex or bend, requiring significant force. A POSITA would also have understood that steel has a Young's modulus approximately 100 times greater than polymers, such as Tritan TX1000. *See* EX2014 at 1-2 (specifying a modulus of approximately 1550 MPa for Tritan TX1000); EX1030 at 7 (showing a modulus of approximately 200 GPa for steel). While Exhibit 2014 is dated from 2020, the properties that I point to in the reference reflect the properties of the same material

by 2014. For example, Cable discloses the same material, Tritan TX1000. *See, e.g.*, EX1006, [0085]. A POSITA would also have understood that aluminum has a modulus approximately 50 times greater than polymers, such as Tritan TX1000. *See* EX2014 at 1-2 (specifying a modulus of approximately 1550 MPa for Tritan TX1000); EX1030 at 7 (showing a modulus of approximately 70 GPa for aluminum). Further, a POSITA would have understood that the flexural strength of steel is approximately 3 to 17 times greater than polymers, such as Tritan TX1000. *See* EX2014 at 1-2 (specifying flexural strength as approximately 60 MPa); EX1030 at 14 (specifying strength of steels between approximately 200 and 1000 MPa). A POSITA would also have understood that the flexural strength of aluminum is approximately 50% less to 8 times greater than polymers, such as Tritan TX1000. *See* EX2014 at 1-2 (specifying flexural strength as approximately 60 MPa for Tritan TX1000); EX1030 at 14 (specifying strength of aluminum alloys between approximately 30 and 500 MPa).

129. Applying these constants to Cable's equations, a POSITA would have understood that the plates of aluminum or steel would need to be very thin to sufficiently bend or flex by 12 millimeters, which would risk deformation, as Cable teaches, and risk being "too thin" according to the '660 Patent such that "heating of the plate produces rippling, bowing, or warping of the plate, resulting in a print surface that is uneven or not consistently level." EX1001, at 4:3-7; EX1006, at

[0086], Fig. 9; *see also* EX1001, at 3:67-4:1 (“thickness of the plate 104 may range from 0.025-0.5”); EX1006, at [0035] (“a basic square shape having a substantially flat surface on which the object 104 is to be formed”). However, Cable does not teach whether a thin plate of steel or aluminum would avoid deformation or warping, nor have Petitioner and Dr. Hickner provided any explanation. Thus, there is no teaching in the Cable-Naware combination of “the material for the thermally conductive plate comprises one or more of aluminum [and] steel” as Petitioner asserts. *See* EX1001, at 6:64-67; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 7.

130. Further, a POSITA would have understood that using steel or aluminum according to Cable would have required substantial experimentation to understand if the particular type of steel or aluminum material and thickness and size of the material could satisfy Cable’s constraints while avoiding the problems with an uneven print surface disclosed by the ’660 Patent. For this additional reason, the combination does not teach claim 7.

E. Claim 11

131. Claim 11 of the ’660 patent recites the “build apparatus of claim 1, wherein a surface of the polymer coating includes nano-, micro-, or milli-meter scale features that increase adhesion to the 3D object.” EX1001, 7:11-13; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 11.

132. I understand that Petitioner asserts that Cable teaches increased object/part adhesion by increasing the “surface energy” of the substrate surface contacting the object. *See* Petition, at 35 (citing EX1006, [0061–0064], [0023], [0036], [0052], [0080]). Petitioner also contends that a POSITA would have known that surface texturing is an obvious technique for increasing surface energy and object/part adhesion. *See* Petition, at 35 (citing EX1003, ¶¶121–122; EX1032, 4:1–8).

133. In my opinion, Petitioner and Dr. Hickner misinterpret Cable. Cable uses the term “surface energy” to describe a property of the material, not to describe a property of how the material is applied or used. Cable recognizes that surface wettability, between the surface of the substrate and the first layer of the object, must be similar to promote adhesion during object formation without forming a permanent bond, which prevents removal of a completed object. *See* EX1006, [0063] (“In this sense, the first material of the substrate 300 at its surface 302 and the second material of the first layer 304 of build material may have “similar” surface energies (within about 10% of each other), and this similarity can promote wetting, which in turn creates sufficient adhesion during the formation of the object 104 so that the object 104 does not move about the substrate 300 during its formation.”), [0064] (“More complete wetting can occur if the substrate 300 has a much higher surface energy than the build material, but this may in turn promote a permanent bond at the

interface between the surface 302 of the substrate 300 and the first layer 304 of the object 104. Since the object 104 is to be removed from the substrate 300 upon completion of the object 104, the adhesion characteristics may be refined by the surface energy relationship noted above.”); *see also* EX1006, [0005] (“a first material having a first surface energy,” “second material can have a second surface energy,” and “where a percent difference between the first surface energy and the second surface energy is within about 10%”), [0081] (“the first material of the substrate 110 has a first surface energy,” “the second material extruded onto the surface of the substrate 110 at 604 has a second surface energy,” and “a percent difference between the first surface energy and the second surface energy is within about 10%”).

134. A POSITA would have recognized that increasing the surface energy, as Petitioner proposes, risks forming a permanent bond between the object and substrate. *See* EX1006, at [0064]. In fact, Dr. Hickner provides an example of increasing the surface energy of polystyrene so that it is 10% *higher* than ABS. EX1003, at ¶122 (“Adding a slight amount of texturing could increase the surface energy of the polystyrene coating, such that it is 10% higher than the ABS, in line with Cable’s preferred embodiment.”). However, Cable expressly states that the surface energies of the materials must be *within* 10% to avoid the risk of permanent bonding. *See* EX1006, at [0005], [0063], [0081]. Moreover, a POSITA would have

understood that in the example of polystyrene and ABS materials, there would have been no motivation to increase the surface energy of polystyrene because the two materials have similar surface energies, within 10% as taught by Cable. *See* EX1036, at 2 (showing ABS with a surface energy of 35 dynes/cm and polystyrene (PS) with a surface energy of 34 dynes/cm). Thus, there is no motivation to modify the combination to add surface texturing, as proposed by Petitioner and Dr. Hickner, because doing so would risk permanent bonding between the object and substrate, preventing the object from being removed upon completion.

135. Thus, there is no teaching in the Cable-Naware combination of the “build apparatus of claim 1, wherein a surface of the polymer coating includes nano-, micro-, or milli-meter scale features that increase adhesion to the 3D object.” EX1001, 7:11-13; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 11.

136. Accordingly, the combination in Ground 1A fails to teach or suggest all the elements of claim 1 and its dependent claims. In addition, the combination of Ground 1A fails to teach or suggest all elements of claims 4, 7, and 11 for the additional reasons I discussed above.

VIII. GROUND 1B: CLAIMS 1–2, 4, 6–12, 15 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 1B (COMBINATION OF CABLE AND KRITCHMAN)

137. In Ground 1B of the Petition, Petitioner asserts that claims 1–2, 4, 6–12, and 15 are obvious over the combination of Cable and Kritchman. Petition at 37–

38 (Overview of Kritchman), 38-40 (Asserted Motivation to Combine and Reasonable Expectation of Success), 41 (1.pre, 1.b, 1.c, 1.c.i, 1.c.ii, 1.c.iii), 41-42 (1.a), 42 (claim 2), 42-43 (claim 4), 43 (claims 6-12 and 15).

138. I have reviewed Petitioner's challenges in Ground 1B, and it is my opinion that Ground 1B fails to teach or suggest all elements of claims 1–2, 4, 6–12, 15. I explain my opinions below in detail.

A. Claims 1, 7, and 11

139. As I explained for Ground 1A, Cable does not teach claim elements 1.c.ii and 1.c.iii in claim 1 and all elements of claims 7 and 11 in the combination with Naware. *Supra* Sections VII.A-B.

140. I understand that Petitioner has not presented any new argument as to claim elements 1.c.ii and 1.c.iii in claim 1 and to claims 7 and 11 in Ground 1B and refers to its arguments for Ground 1A. *See* Petition, at 41, 43. Thus, it is my opinion that Ground 1B fails to teach or suggest claim elements 1.c.ii and 1.c.iii in claim 1 and all elements of claims 7 and 11 for the reasons I discussed above for Ground 1A.

B. Claim 4

141. Claim 4 of the '660 Patent recites the “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.”

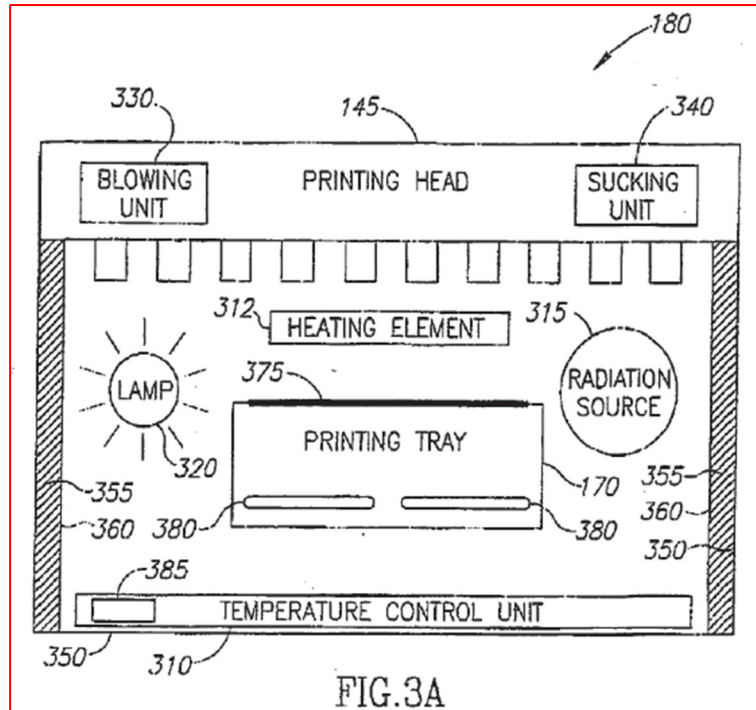
EX1001, 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

142. I understand that Petitioner asserts for Ground 1B, similar to its assertion for Ground 1A, that a POSITA would have been motivated to consider thermocouples as a design choice in selecting sensors. *See* Petition, at 42-43 (citing EX1009, at [0007], [0027], [0091]-[0096], Figs. 1, 2A, 2D, cls. 133-137; EX1003, at ¶143).

143. In my opinion, it would not have been obvious to a POSITA to try thermocouples with Kritchman’s design in the Cable-Kritchman combination. Dr. Hickner only recognizes two options: thermocouples and thermistors. EX1003, at ¶143. However, as I explained above for Ground 1A, a POSITA would have understood that there are thousands of options for measuring surface temperature, including hundreds of types of RTDs, thousands of types of semiconductor-based temperature sensors, and many non-contact temperature sensors, such as infrared imaging devices. *Supra* Section VII.C (Ground 1A, claim 4); EX2011, at 1-2; EX2012, at 1-3; EX2013, at 1; EX2015, EX2016. Accordingly, thermocouples are not simply one of a finite set of solutions for measuring surface temperature.

144. Further, a POSITA would have understood that there is no motivation to try using thermocouples in Kritchman’s design. Paragraph [0027] of Kritchman, which Petitioner cites to, discloses that “the temperature of *an object* being printed

may be controlled” using “an electromagnetic radiation associated with the device, electromagnetic radiation independent of the curing device, exothermic chemical curing, a heating element, a cooling element, and/or other suitable temperature control elements, such as a temperature sensor and controller that operates the cooling and heating elements according to the sensor reading and required temperature” in which the “material of the upper layer(s) may be heated before depositing.” EX1009, at [0027]. As Kritchman explains, that its “[p]rinting sub-system 180 may include a temperature sensing unit 385, optionally associated with temperature control unit 310, to sense the temperature of cell 180, tray 170, building, materials etc.” *Id.* at [0099] The “electromagnetic radiation associated with the device” may be included in system 180 as “an electromagnetic radiation source 315, to enable heating of the building material before, during, and/or after deposition.” *Id.* In addition, “[p]rinting sub-system 180 may include an electromagnetic lamp 320, for curing and/or warming of printed objects.” *Id.* And, “higher temperatures of the upper material layers may be maintained by . . . warming the upper layers by heating element 312.” *Id.* at [0101].



Id. at Fig. 3A. A POSITA would have recognized that Kritchman teaches temperature sensing for many components of sub-system or cell 180, including tray 170 and the building materials as they are heated by the heating element 312, radiation source 315, and lamp 320. To measure the temperature of the changing surface, such as the shape and location, of the building materials, a POSITA would have recognized that thermocouples, which are typically affixed to a surface, would not have been used to sense temperature. Instead, a POSITA would have recognized that non-contact temperature sensors, such as an infrared sensor, would have been used to measure temperature according to Kritchman's teachings. *See* EX2015, at 1-3; EX2016, at 1-2.

145. Thus, there is no teaching in the Cable-Kritchman combination of a “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.” EX1001, at 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

146. Accordingly, the combination in Ground 1B fails to teach or suggest all the elements of claim 1 and its dependent claims. In addition, the combination of Ground 1B fails to teach or suggest all elements of claim 4 for the additional reasons I discussed above.

IX. GROUND 1C: CLAIMS 7–8, 14 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 1C (COMBINATION OF CABLE, NAWARE OR KRITCHMAN, AND COMB)

147. In Ground 1C of the Petition, Petitioner asserts that claims 7-8 and 14 are obvious over the combination of Cable, Naware or Kritchman, and Comb. Petition at 43-44 (Asserted Motivation to Combine and Reasonable Expectation of Success), 44-45 (claim 7), 45 (claims 8 and 14).

148. I have reviewed Petitioner’s challenges in Ground 1C, and it is my opinion that there is no motivation to combine Comb with combinations including Cable (Cable and Naware (Ground 1A), and Cable and Kritchman (Ground 1B)). Because claims 7-8 and 14 depend from claim 1, they include the elements of claim 1. Because Petitioner has not separately challenged claim 1 in Ground 1C, it is my opinion that Ground 1C fails to teach or suggest all elements of claims 7-8 and 14

for the reasons I discussed above for Grounds 1A and 1B. *Supra* Sections VII.A, VII.B, VIII.A. It is also my opinion that Ground 1C fails to teach or suggest all elements of claims 7 and 14. I explain my opinions below in detail.

A. There is no motivation to combine Comb with Cable and Naware (Ground 1A) and with Cable and Kritchman (Ground 1B)

149. As I discussed above, Petitioner relies on Cable's teachings for claim elements 1.c.ii ("a polymer coating which is capable of . . . ") and 1.c.iii ("wherein the polymer coating is not a polymer tape") in Ground 1A and 1B. *Supra* VII, VIII.

150. I understand that Petitioner asserts that Cable teaches a substrate comprised of metal and that a POSITA would have been motivated to use Comb's disclosure of specific metals, aluminum and steel, in the combination and have had a reasonable expectation of success in doing so. *See* Petition, at 43-44.

151. In my opinion, a POSITA would have understood that there is no motivation to combine Cable and Comb in the manner that Petitioner proposes and that there is no reasonable expectation of success in doing so. A POSITA would have recognized that Comb teaches thicknesses for its base sheet 36b that "range from about 5 mils to about 100 mils" with preferences for specific ranges within that specification, such as "more preferably from about 5 mils to about 50 mils." EX1004, at 8:51-65.

152. As I discussed above for claim 7 of Ground 1A, Cable explains that its substrate's material must be able to "bend or flex resiliently" by about 12

millimeters. EX1006, at [0077]; *see also id.* [0068]-[0072], Abstract, [0006]; *supra* Section VII.D (claim 7 of Ground 1A). For example, Cable teaches that a 4-millimeter-thick copolyester substrate cannot bend or flex resiliently to remove a complete object. *See id.* at [0085]-[0087], Figs. 7-11. Accordingly, a POSITA would have recognized Cable teaches that the thinnest steel or aluminum plate taught by Comb (5 millimeters) would not have bent or flexed resiliently to remove a completed object. *See id.* at [0068]-[0072], [0085]-[0087], Figs. 7-11. Thus, Cable does not teach using Comb's plate.

153. Further, if a POSITA were to consider plates thinner than those taught by Comb, contrary to Comb's teachings, a POSITA would have needed to experiment, according to Cable's teachings and Comb's teachings, to determine whether any thickness of steel or aluminum substrate could satisfy the teachings of both references to provide a resilient material that bends and flexes with a deflection of 12 millimeters to remove an object after fabrication. *Supra* Section VII.D (discussing Cable's teachings in detail for Ground 1A, claim 7); *see also* EX1004 (Comb), at 8:51-65 (specifying thickness of build sheet, including base sheet 36b and top film 36a), 10:26-57 (disclosing magnetic coupling dependent on thickness of base sheet 36b and build sheet 36). As I discussed in Sections VII.A and VII.D, Cable provides three examples with a copolymer. EX1006 (Cable), [0085]-[0087], Figs. 7-11; *supra* Sections VII.A (Ground 1A, claim 1), VII.D (Ground 1A, claim

7). Each of the examples exhibits issues with bending or flexing the substrate to properly remove the completed object without leaving behind visible residue, using a blade for removing the object, and/or deforming the substrate. *See id.* In addition, Cable provides a Comparable Example 1 in which the object became detached from a glass substrate during a build. *See* EX1006 (Cable), ¶[0088]. As Cable recognizes, there may be multiple theories for this failure. *See id.* (“Without being tied to any particular theory”). And, Cable speculates that the failure might have been related to “the differences between the physical characteristics of the substrate and the material of the object” and “lack of heating of the 3D printer platform.” *Id.* Thus, a POSITA would not have had a reasonable expectation of success in using a steel or aluminum substrate from Comb in a combination with Cable. Thus, Ground 1C does not teach any of the challenged claims of the ’660 Patent because there is no motivation to combine Comb with the combinations involving Cable (Cable-Naware-Comb and Cable-Kritchman-Comb).

B. Claim 7

154. Claim 7 of the ’660 Patent recites the “build apparatus of claim 1, wherein the material for the thermally conductive plate comprises one or more of aluminum, steel, brass, ceramic, glass, or alloys with a low coefficient of thermal expansion (CTE).” EX1001, at 6:64-67; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 7.

155. I understand that Petitioner has asserted that Comb’s teaching of steel as a preferred material would have been combined in the Cable-Naware-Comb and Cable-Kritchman-Comb combinations. *See* Petition, at 44-45.

156. As I discussed above, a POSITA would have understood that there is no motivation to combine Comb in these combinations. *Supra* Section IX.A. Accordingly, there is no motivation to combine Comb’s steel substrate in the Cable-Naware-Comb and Cable-Kritchman-Comb combinations. *See also supra* Section VII.D (claim 7 for Ground 1A).

157. Thus, there is no teaching in the Cable-Naware-Comb and Cable-Kritchman-Comb combinations of “the material for the thermally conductive plate comprises one or more of . . . steel” as Petitioner asserts. *See* EX1001, 6:64-67; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 7.

C. Claim 14

158. Claim 14 of the ’660 Patent recites the “build apparatus of claim 1, wherein the build platform has a first coefficient of thermal expansion (CTE) and the thermally conductive plate has a second CTE, wherein the first CTE is greater than the second CTE.” EX1001, at 7:21-24; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 14.

159. I understand that Petitioner has asserted that the combination includes a steel substrate and aluminum build platform according to Comb’s teachings. *See*

Petition, at 45 (citing EX1004, at 7:29–37, 8:17–33, 6:64–7:6, 6:17–23, 8:51–9:11, 11:12–20, Figures 2–7).

160. As I discussed above, a POSITA would have understood that there is no motivation to combine Comb in these combinations. *Supra* Section IX.A. Accordingly, there is no motivation to combine Comb’s steel substrate in the Cable-Naware-Comb and Cable-Kritchman-Comb combinations. *See also supra* Section VII.D (claim 7 for Ground 1A).

161. Thus, there is no teaching in the Cable-Naware-Comb and Cable-Kritchman-Comb combinations of “build apparatus of claim 1, wherein the build platform has a first coefficient of thermal expansion (CTE) and the thermally conductive plate has a second CTE, wherein the first CTE is greater than the second CTE” as Petitioner asserts. *See* EX1001, 6:64-67; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 14.

162. Accordingly, the combination in Ground 1C fails to teach or suggest all the elements of claim 1 and its dependent claims. In addition, the combination of Ground 1C fails to teach or suggest all elements of claims 7 and 14 for the additional reasons I discussed above.

X. GROUND 2A: CLAIMS 1–3, 5-15 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 2A (COMBINATION OF COMB AND TUMMALA)

163. In Ground 2A of the Petition, Petitioner asserts that claims 1–3 and 5–15 are obvious over the combination of Comb and Tummala. *See* Petition, at 46-47

(Overview of Comb), 48-49 (Overview of Tummala), 49-53 (Asserted Motivation to Combine), 53 (Asserted Reasonable Expectation of Success), 54 (1.pre), 55-58 (1.a), 59 (1.b), 60 (1.c), 61 (1.c.i), 62-68 (1.c.ii), 58-59 (1.c.iii), 69-70 (claim 2), 70 (claim 3), 71 (claim 5), 71-72 (claim 6), 72 (claim 7), 72 (claim 8), 72-73 (claim 9), 73 (claims 10 and 11), 74 (claims 12–14), 75 (claim 15).

164. I have reviewed Petitioner’s challenges in Ground 2A, and it is my opinion that Ground 2A fails to teach or suggest all elements of claims 1–3 and 5–15. I explain my opinions below in detail.

A. Claim 1, Elements 1.c.i, 1.c.ii

165. Claim 1 of the ’660 Patent requires, among other elements, “a polymer coating . . . which is capable of (i) facilitating adhesion to the 3D object during printing and (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.” EX1001, at 6:39-46; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim Elements 1.c.i and 1.c.ii.

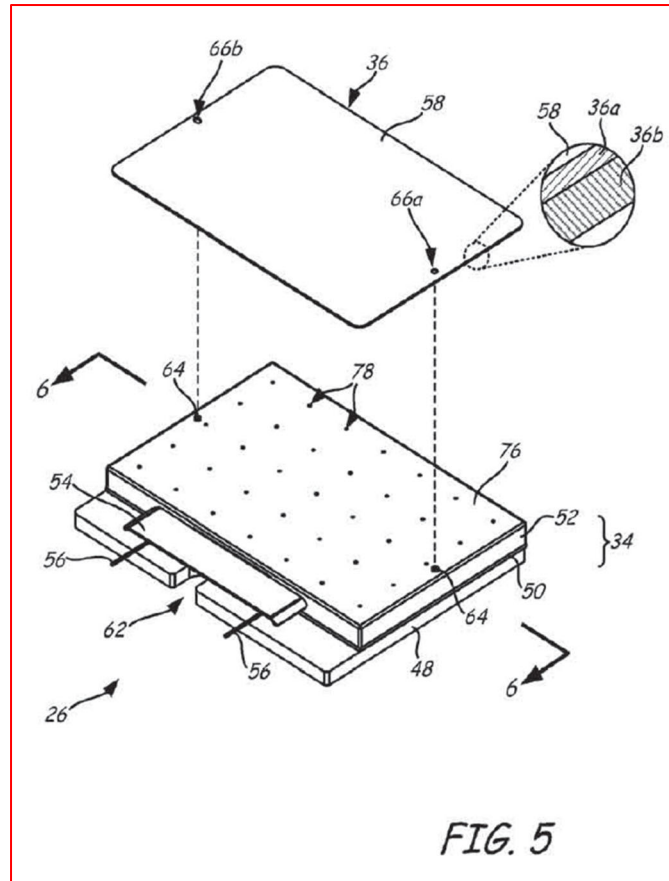
166. I understand that Petitioner contends that Comb teaches its polymer coating is capable of facilitating good adhesion to the part. *See* Petition, at 61 (citing EX1004, at 8:43–50, 13:36–48). I also understand that Petitioner asserts that the combination incorporates Tummala’s teachings regarding the formulation of the

polymeric coating that provides bonding to the extruded print material. *See* Petition, at 61 (citing EX1005, at [0007], [0023], [0028], [0034], [0043], [0045], [0052], [0063]). Petitioner also asserts that the combined teachings of Comb and Tummala teach permitting removal of the 3D object for claim element 1.c.ii. *See* Petition, at 62-68. Further, I understand that Petitioner has asserted that in the combination of Comb and Tummala, a POSITA would have found it obvious to apply a non-tape polymer coating in view of Tummala's teachings. *See* Petition, at 49. I also understand that Petitioner has asserted that, alternatively, a POSITA would have found it obvious to apply Comb's polymer or Tummala's polymer as a gel. *See id.*

167. It is my opinion that the combination of Comb and Tummala do not teach a polymer coating . . . which is capable of (i) facilitating adhesion to the 3D object during printing and (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object. I discuss the teachings of Comb and Tummala in detail below.

1. Comb's Coating

168. A POSITA would have recognized that Comb teaches a polyimide tape coating for its build sheet 36, which is shown below in Figure 5 of Comb.



EX1004 (Comb), at Fig. 5. Comb says what the top film 36a is derived from. Namely, Comb says the film “may be derived from one or more polymeric coatings, tapes, or other lamina.” *Id.* at 8:27-29; *see also id.* at 8:43-44 (“The top film 36a, as an adhesive tape or other coating adhered to base sheet 36b”). Comb also says the film is “laminated on or otherwise adhered to” the base sheet 36b. *Id.* at 8:20-23. As I explained above for Ground 1A, I disagree with Petitioner’s assertion that the use of the term “coating” connotes a structure that is not tape. *Supra* Section VII.B; *see also* EX1001, at 1:54-56; EX1011 at 269; EX2017, at 14. A POSITA would have understood that a coating can commonly refer to a tape that is used in the process of

making a coating surface. *See id.* Further, it was known that tapes were used as a laminate in multi-layer applications. *See id.*; *see also* EX2017, at 22; EX1001, at 1:59-62; EX1011, at 269. Thus, a POSITA would have recognized that Comb is merely describing source materials from which top film 36a is derived from and that the film can be laminated on or otherwise adhered to the base sheet in a manner consistent with the use of tapes.

169. In addition, I discussed above that Comb provides three examples of its top film 36a: polycarbonate film, polyimide tapes, and tapes with lower glass transition temperatures. *See* EX1004 (Comb), at 8:29-42; *supra* Section VI.A (Overview of Comb). A POSITA would have recognized that each of these examples describes using a tape to apply a coating. Further, a POSITA would have recognized that for applications with a heated build platform where high-temperature part materials are used, Comb teaches the use of polyimide tape. *See id.* at 8:34-39. Thus, Comb does not teach a non-tape polymeric coating as recited in claim element 1.c.iii.

170. Further, a POSITA would have recognized that it would not apply Comb's polyimide material, which Comb discloses is a polyimide tape, as a gel according to Tummala's teachings. Tummala teaches that its adhesive "is a viscous gel at room temperature." EX1005 (Tummala), at [0053]. Indeed, many of Tummala's embodiments use an adhesive that includes polyvinyl alcohol or PVOH. *See id.* at Abstract, [0028]; *see also id.* at [0009], [0010], [0024], [0031], [0063].

While making a gel out of PVOH at room temperature, as Tummala teaches, is feasible, a POSITA would have recognized that it would have been difficult and impractical to make a gel out of thermoplastic polyimide at room temperature, requiring experimentation with environmentally unfriendly solvents. *See* EX1005 (Tummala), at [0058] (“an adhesive described herein can be safely dissolved and/or rinsed away from a print pad or finished part, including down the sink and/or into the environment”). Tummala does not suggest using a polyimide gel at room temperature and a POSITA would not have understood Tummala to teach such a gel. Thus, a POSITA would not have found it obvious to apply Comb’s polymer as a gel. *See* Petition at 49 (EX1003, ¶162).

2. Tummala’s Coating

171. As I discuss below, a POSITA would have recognized that Tummala, as used in combination with Comb, does not teach a coating that both facilitates adhesion to the 3D object during printing and permits removal of the 3D object once it has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.

172. First, a POSITA would have understood that, while Tummala’s print pad may be reusable, Tummala’s coating is not reusable and must be applied at the start of each print. *See* EX1005 (Tummala), [0006]. As the ’660 Patent recognizes,

its coating does not wear away, unlike polyimide tape coatings. *See, e.g.*, EX1001, at 6:11-15, 4:52-54. As I discussed above for Tummala, the reference discloses method for printing a 3D article or object in which the first step is to apply “an adhesive to a build surface of a print pad of a 3D printer” which is done “prior to [the] beginning of a printing process” to deposit layers for a printed object. EX1005, at [0010], [0023]; *see also id.* [0053], [0063], [0064]; *supra* Section VI.B (Overview of Tummala). A POSITA would have recognized that Tummala’s teaching to apply its adhesive for each print is consistent with Tummala’s teaching that many of its embodiments use an adhesive that includes polyvinyl alcohol or PVOH that is water-soluble and does not adhere to the print pad permanently. *See* EX1005 (Tummala), at [0058] (“Therefore, in some embodiments, an adhesive described herein can be safely dissolved and/or rinsed away from a print pad or finished part, including down the sink and/or into the environment.”); *see also id.* at [0009], [0010], [0024], [0028], [0031], [0063], cls. 1, 20.

173. A POSITA would have understood that Tummala’s polymer coating is regularly reapplied due to damage, whereas Tummala’s print pad itself will not be damaged. *See* EX1005, at [0050] (“in some embodiments, use of an adhesive described herein permits print materials and/or printed parts to be removed or peeled from the print pad easily, without breaking, and/or without the use of tools”), [0005] (“a hand tool such as a scraper [is used] to separate the printed 3D object from the

print pad, which can lead to damage to the printed 3D object and/or the surface of the print pad”), [0006] (“a need exists to improve the printing of 3D objects to provide accurate parts, models, and other 3D objects that are easily and safely removed from the print pad”). Thus, the combination with Comb and Tummala does not teach a coating that permits removal of the 3D object once it has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating.

174. Second, a POSITA would have understood that Tummala’s general statements, when interpreted by Tummala’s entire disclosure, teach that chemical removal is typically required once the 3D object has formed and cooled. Tummala indicates that “removing the 3D article from the print pad comprises altering the adhesive property of the adhesive.” EX1005, at [0010]; *see also id.* at [0023], [0059], [0060], [0068].

175. Tummala provides general statements about its adhesive. Tummala states that its adhesive has a bonding strength between 2 and 50 times greater at 100° C than at room temperature. *Id.* at ¶[0047]. Similarly, Tummala’s adhesive has a bonding strength between 2 and 60 times greater when dry than when wet at 23° C. *Id.* at ¶[0048]. Accordingly, “in some embodiments,” Tummala’s adhesives “permit adhesion of a print material or printed part to a print pad throughout the print process until the part is complete” and permit “print materials and/or printed parts to be

removed or peeled from the print pad easily, without breaking, and/or without the use of tools.” *Id.* at ¶[0050]; *see also id.* at [0005] (“[A] strong bond can prevent the extruded print material from separating from the print pad prematurely but may also make it difficult to remove the printed 3D object and any support material from the print pad following completion of the print process. Further, this difficulty can require a user to employ a hand tool such as a scraper to separate the printed 3D object from the print pad, which can lead to damage to the printed 3D object and/or the surface of the print pad.”).

176. However, a POSITA would have interpreted Tummala’s general statements in view of Tummala’s entire disclosure. Tummala explains that its adhesive “has adhesive properties that are tunable or selectable, so that the adhesive can act as both a bonding agent and a releasing agent.” *Id.* at ¶[0046]. A bonding agent “bond[s] a print material or printed part to a print pad” and a releasing agent “facilitates release or separation of a print material or printed part from a print pad.” *Id.* Tummala also provides Table I to show the properties of its adhesives as bonding and releasing agents. *See id.* As shown below in Table I, Tummala tested its adhesives on different footprints (2x2 and 3x3), raft configurations (raft and no raft), print pads (anodized aluminum and coarse grind textured glass), temperatures (100° C and 23° C), and dry/wet conditions.

TABLE I					
Footprint	Raft	Print Pad	100° C. (Dry)	23° C. (Dry)	23° C. (Wet)
2 × 2	raft	anodized aluminum	>20 lbs	0-0.5 lbs	0-0.5 lbs
2 × 2	no raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
2 × 2	no raft	Course Grind textured glass	—	>20 lbs	0-0.5 lbs
3 × 3	raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
3 × 3	no raft	anodized aluminum	>20 lbs	19 lbs	0-0.5 lbs

Id. at ¶[0046]. For each configuration of footprint, raft configuration, and print pad, Tummala provides the bonding strength under three different conditions (100° C, Dry; 23° C Dry, and 23° C Wet). *See id.* Tummala states that the “labels ‘Dry’ and ‘Wet’ refer to whether or not the print pad and part were submerged in water.” *Id.* Tummala also explains that for “entries in Table I below having an adhesion or bonding strength greater than 20 pounds, the parts broke before the parts separated from the print pad.” *Id.* Accordingly, a POSITA would have recognized that a bonding strength between 0 and 0.5 pounds would have enabled parts to separate without breaking.

177. As shown by my annotations below to Table I of Tummala, each of configurations enable the parts to separate when “submerged in water” under the “Wet” condition. A POSITA would have recognized that water is a solvent that is used for chemical separation. *See* EX1005, [0046], [0036] (“a solvent comprises

water”), [0037], [0068]. Thus, in these conditions, Tummala (as used in the combination with Comb) does not teach permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object.

TABLE I

Footprint	Raft	Print Pad	100° C. (Dry)	23° C. (Dry)	23° C. (Wet)
2 × 2	raft	anodized aluminum	>20 lbs	0-0.5 lbs	0-0.5 lbs
2 × 2	no raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
2 × 2	no raft	Course Grind textured glass	—	>20 lbs	0-0.5 lbs
3 × 3	raft	anodized aluminum	>20 lbs	>20 lbs	0-0.5 lbs
3 × 3	no raft	anodized aluminum	>20 lbs	19 lbs	0-0.5 lbs

separation with raft

broken parts

“wet” separation

178. Also shown by my annotations to Table I above, a POSITA would have understood that Tummala’s configurations requiring around 20 pounds of force or greater would have resulted in broken parts upon part removal. *See* EX1005, at [0046] (“For entries in Table I below having an adhesion or bonding strength greater than 20 pounds, the parts broke before the parts separated from the print pad.”). Thus, in these conditions, Tummala (as used in the combination with Comb) does

not teach permitting removal of the 3D object once the 3D object has been formed and cooled without damaging the 3D object.

179. In addition, one of the conditions requires the use of a raft for separation at a dry room temperature condition. As Tummala teaches, the raft is used as an intermediary between the object being printed and the print pad. EX1005, at ¶[0004] (“[T]he print material is deposited . . . a ‘raft’ of support material disposed on the print pad[], which can result in the formation of a bond . . . between the surface of the raft and the surface of the print pad[.]”). Tummala explains that the raft must separately be removed from the object itself. *See id.* at ¶[0021] (“However, unlike the print material, the support material is subsequently removed to provide the finished three-dimensional part.”); *see also* EX1001 (’660 Patent), at 5:20-25 (“Therefore once the building of the object is finished, the object will pop off the plate 104 when the plate and part have cooled. This efficiently avoids the general issue in the current art, . . . having to remove the object from a support raft requiring an additional step to dissolve or mechanically remove the support from the part.”). Thus, a POSITA would have recognized that the raft that adheres at high temperatures (e.g., 100° C) is not the 3D object itself, which must be chemically or mechanically removed. Thus, in Tummala’s configurations requiring a raft for object removal, Tummala (as used in the combination with Comb) does not teach facilitating adhesion to the 3D object during printing.

180. Thus, there is no teaching in the Comb-Tummala combination of “a polymer coating . . . which is capable of (i) facilitating adhesion to the 3D object during printing and (ii) permitting removal of the 3D object once the 3D object has been formed and cooled without chemically or mechanically removing the polymer coating from 3D object and without damaging the polymer coating, the thermally conductive plate, or the 3D object.” EX1001, at 6:39-46; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim Elements 1.c.i and 1.c.ii.

B. Claim 11

181. Claim 11 of the ’660 patent recites the “build apparatus of claim 1, wherein a surface of the polymer coating includes nano-, micro-, or milli-meter scale features that increase adhesion to the 3D object.” EX1001, at 7:11-13; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 11.

182. I understand that Petitioner asserts that it would have been obvious to surface treat a coating to add texture (nano-, micro-, or milli-meter scale features). *See* Petition, at 73 (citing EX1003, at ¶224; EX1032, at 4:1-8).

183. In my opinion, a POSITA would not have understood the combination in Ground 2A to teach claim 11. First, a POSITA would have recognized that surface treating the coating in the Comb-Tummala combination would substantially increase the cost of operation. As I explained for claim 1, Tummala teaches applying its adhesive as the first step at the start of each print. *Supra* Section X.A.2 (Ground 2A,

Claim 1, Tummala's Coating); *see also* EX1005, at [0006], [0010], [0023], [0063]-[0064]. A POSITA would have recognized that surface treating an adhesive that is applied at the start of each print would have been time consuming and costly and thus a POSITA would not have been motivated to add surface treatment.

184. Further, surface treatment of Tummala's coating risks damage to the coating, which would impair or prevent the coating from being used for a print. Tummala teaches that its coating, which is applied as a gel, has a thickness of only 0.01 to 0.1 millimeters, or 10 to 100 micrometers. *See* EX1005, at [0045] ("Second, a single coat of an adhesive described herein was applied to a 100 mm×100 mm area of the print pad surface using an applicator with a sponge tip, providing a coating thickness of 0.05-0.1 mm."), [0055] ("For example, in some embodiments, an adhesive having a dynamic viscosity greater than about 4000 cP at 30° C. provides a uniform adhesive layer thickness of about 10 μm when applied to a print pad described herein."). Petitioner points to another reference that discloses a surface roughness of between 5 and 25 microns. *See* Petition at 73 (citing EX1032, at 4:1-8). However, a POSITA would have recognized that applying such a surface treatment with a roughness between 5 and 25 microns would have risked damage to the coating without a reasonable expectation of success with using a coating according to Tummala's teachings. For example, the coating may become too thin or wear away completely at certain points, impeding adhesion during printing or

easy object removal after the print is complete. *See* EX1005 (Tummala), at [0006] (“in some embodiments, use of an adhesive described herein permits print materials and/or printed parts to be removed or peeled from the print pad easily, without breaking, and/or without the use of tools”), [0046] (bonding agent and releasing agent for adhesive).

185. Thus, there is no teaching in the Comb-Tummala combination of the “build apparatus of claim 1, wherein a surface of the polymer coating includes nano-, micro-, or milli-meter scale features that increase adhesion to the 3D object.” EX1001, 7:11-13; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 11.

186. Accordingly, the combination in Ground 2A fails to teach or suggest all the elements of claim 1 and its dependent claims. In addition, the combination of Ground 2A fails to teach or suggest all elements of claim 11 for the additional reasons I discussed above.

XI. GROUND 2B: CLAIMS 1-15 WOULD NOT HAVE BEEN OBVIOUS OVER GROUND 2A (COMBINATION OF COMB, TUMMALA, AND KRITCHMAN)

187. In Ground 2B of the Petition, Petitioner asserts that claims 1–15 are obvious over the combination of Comb, Tummala, and Kritchman. *See* Petition, at 76-77 (Asserted Motivation to Combine and Reasonable Expectation of Success), 77 (1.pre, 1.b, 1.c, 1.c.i, 1.c.ii, 1.c.iii), 77-78 (1.a), 78 (claims 2-3), 79 (claims 4–15).

188. I have reviewed Petitioner’s challenges in Ground 2B, and it is my opinion that Ground 2B fails to teach or suggest all elements of claims 1–15. I explain my opinions below in detail.

A. Claim 1

189. As I explained for Ground 2A, the combination of Comb and Tummala does not teach claim elements 1.c.i and 1.c.ii in claim 1 and all elements of claim 11. *Supra* Section X.

190. I understand that Petitioner has not presented any new argument as to claim elements 1.c.i and 1.c.ii in claim 1 and to the claim elements in claim 11 in Ground 2B and refers to its arguments for Ground 2A. *See* Petition, at 77, 79. Thus, it is my opinion that Ground 2B fails to teach or suggest claim elements 1.c.i and 1.c.ii in claim 1 and the claim elements of claim 11 for the reasons I discussed above for Ground 2A.

B. Claim 4

191. Claim 4 of the ’660 Patent recites the “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.” EX1001, at 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

192. I understand that Petitioner asserts for Ground 2B, similar to its assertions for Grounds 1A and 1B, that a POSITA would have been motivated to consider thermocouples as a design choice in selecting sensors in the combination. *See* Petition, at 79 (citing EX1009, [0007], [0027], [0073], [0091]-[0096], Figs. 1, 2A, 2D, cls. 133-137; EX1003, ¶¶241-244).

193. As I explained for Ground 1B, it would not have been obvious to a POSITA to try thermocouples with Kritchman's design. *Supra* Section VIII.B (Ground 1B, claim 4). For the same reasons, a POSITA would not have been motivated to try thermocouples in the combination of Ground 2B. A POSITA would have understood that there are thousands of options for measuring surface temperature, including hundreds of types of RTDs, thousands of types of semiconductor-based temperature sensors, and many non-contact temperature sensors, such as infrared imaging devices. *Supra* Sections VII.C (Ground 1A, claim 4); VIII.B (Ground 1B, claim 4); EX2011, at 1-2; EX2012, at 1-3; EX2013, at 1; EX2015, EX2016. Accordingly, thermocouples are not simply one of a finite set of solutions for measuring surface temperature.

194. Further, as I explained for Ground 1B, a POSITA would have understood that there is no motivation to try using thermocouples in Kritchman's design. *Supra* Section VIII.B (Ground 1B, claim 4); *see also* EX1009 (Kritchman), [0027], [0099], [0101], Fig. 3A; EX2015, at 1-3; EX2016, at 1-2. For the same

reasons, a POSITA would not have been motivated to try thermocouples in the combination of Ground 2B.

195. Thus, there is no teaching in the Comb-Tummala-Kritchman combination of a “build apparatus of claim 1, wherein the build platform comprises thermocouples situated at one or several locations to provide feedback to a controller for maintaining temperature set points.” EX1001, at 6:53-56; *supra* Section II (“The Challenged Claims of the ’660 Patent”), Claim 4.

196. Accordingly, the combination in Ground 2B fails to teach or suggest all the elements of claim 1 and its dependent claims. In addition, the combination of Ground 2B fails to teach or suggest all elements of claim 4 for the additional reasons I discussed above.

XII. CONCLUSION

197. For the reasons set forth above, it is my opinion that claims 1-15 of U.S. Patent No. 9,592,660 would not have been obvious to a person of ordinary skill in the art at the relevant time.

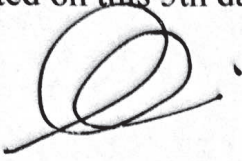
198. In signing this Declaration, I understand it will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I understand I may be subject to cross-examination in this case, and that any cross-examination will take place in the United States. If cross-

examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

199. I declare that all statements made herein of my knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

200. I declare under penalty of perjury under the laws of the United State that the forgoing is true and correct.

Executed on this 5th day of September, 2025.

A handwritten signature in black ink, consisting of a large, stylized 'O' followed by a horizontal line and a small flourish.

Dr. Tim A. Osswald

APPENDIX A

Professor Tim A. Osswald

Professor Emeritus - University of Wisconsin-Madison

Honorary Professor at the Friedrich-Alexander University, Erlangen, Germany

Honorary Professor at the National University, Bogotá, Colombia

co-Director of the Polymer Engineering Center

EDUCATION:

PhD	1987	University of Illinois-Urbana, Mechanical Engineering
MS	1982	South Dakota School of Mines & Tech., Mechanical Engineering
BS	1981	South Dakota School of Mines & Tech., Mechanical Engineering
H.S.	1975	S.D.S.J.C, Cúcuta, Colombia

POSITION HELD:

2008-2009	Interim Chair of Plastics Technology, University of Erlangen-Nuremberg (from August 1, 2008 to February 28, 2009)
1999-2024	Professor, Department of Mechanical Engineering, and co-Director of the Polymer Engineering Center, UW
1995-1999	Associate Professor, Department of Mechanical Engineering, UW
1989-1995	Assistant Professor, Department of Mechanical Engineering, UW
1987-89	Humboldt Fellow: Institute for Plastics Processing (IKV), Technical University of Aachen (RWTH), West Germany
1987-89	Consultant: Dynamit Nobel, Leverkusen, Germany
1986	College Graduate in Training: GM Research Labs
1982-83	Instructor: Mechanical Engineering , SDSM & T, SD

HONORS AND AWARDS:

- Journal of Polymer Composites, Editor (2021-present)
- Advisor to the Colombian President on Science and Technology (2019-present)
- Member of the 2019 Commission to create a Science Ministry in Colombia
- Sabic Educator of the Year - SPE Composites Division (2017)
- Fred E. Schwab Education Award - National SPE Educator Award (2016)
- SPE Educator of the Year Award - Milwaukee, Wisconsin (2016)
- Honorary Professor - National University of Colombia (2010)
- Fellow of the Society of Plastics Engineers (2008)
- Honorary Professor - University of Erlangen-Nuremberg (2006)
- Chaired Professorship: K.K. and Cindy Wang Professor (2005-2015)
- Journal of Polymer Technology, Editor (2004-present)
- Nominated as the first American member of the International Alliance of Polymer Technology Professors (2002)
- Recipient of the VDI-K Dr.-Richard-Escales-Prize (2001)
- Journal of Polymer Engineering, Editor for the Americas, (1999-present)
- Hanser Publishers, Advisory Board, (1998-present)
- Journal of Society of Manufacturing Engineers, Editor -- Plastics
- NSF Presidential Young Investigator Award (1991-96)
- Alexander von Humboldt Fellow (1987-89)

PERSONAL INFORMATION:

Married, two children. Born in Bogotá, Colombia, US Citizen,
Fluent in English, German and Spanish. Communicates in French,
Italian and Portuguese

Professor Tim A. Osswald

BOOKS

1. Osswald, T.A., and Román, A.J., *Understanding Polymer Processing*, 3rd Edition, Hanser Verlag, München, 2024
2. Baur, E., Drummer, D., Osswald, T.A., and Rudolph, N., *Saechtling Kunststoff-Taschenbuch*, 32st Edition, 2022. (German Plastics Handbook that appeared for the first time in 1936)
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15. Osswald, T.A. and G. Menges, *Materials Science of Polymers for Engineers*, 2nd Edition, Hanser Verlag, München, 2003. Spanish Translation 2009.
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17. Osswald, T.A., *Polymer Processing Fundamentals*, Hanser Verlag, München, 1998. Spanish translation 2008.
18. Osswald, T.A. and G. Menges, *Materials Science of Polymers for Engineers*, Hanser Verlag, München, 1996. The book's Japanese edition appeared in 1997, and Korean edition in 1999.
19. Comer, J.J., T.A. Osswald and R.L. Pendleton, *An Introduction to Experimental Analysis of Stress and Strain*, SDSM & T Press, 1983.

Edited the following series (Plastics Pocket Power series)

1. Naranjo/Noriega/Sierra/Sanz *Extrusion Processing Data*, Plastics Pocket Power Series, T.A. Osswald, Editor, Hanser Publishers, Munich, 2001
2. Naranjo/Noriega/Sierra/Sanz, *Injection Molding Processing Data*, Plastics Pocket Power Series, Osswald, T.A. Editor, Hanser Publishers, Munich, 2001
3. Thielen, *Extrusion Blow Molding*, Plastics Pocket Power Series, Osswald, T.A. Editor, Hanser Publishers, Munich, 2001
4. Benatar/Grewell/Bonten Tuechert, *Welding*, Plastics Pocket Power Series, Osswald, T.A. Editor Hanser Publishers, Munich, 2001
5. Bonten, *Aging and Chemical Degradation*, Plastics Pocket Power Series, Osswald, T.A. Editor, Hanser Publishers, Munich, 2001
6. DeGreiff/Naranjo/Castaño, *Applied Rubber Technology*, Plastics Pocket Power Series, Osswald, T.A. Editor, Hanser Publishers, Munich, 2001

New Course Development and Major Course Revisions

Developed ME 310, Manufacturing: Polymers (2021).

This is a course based in part on ME313 and ME314 which are being phased out. The course has 28 lectures and 12 laboratory units ranging from hands-on experiments on polymer processing equipment to process modeling. Professor Osswald wrote the textbook *Understanding Polymer Processing*, Hanser (2010, 2017) that will be used in this course. A new edition of this book is being prepared.

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Revised ME 313, Manufacturing Processes-Plastics (1993).

This is a 7 week course taught two times a semester. It describes fundamentals of plastics manufacturing processes in a series of 14 lectures and 6 laboratories. For this course Osswald wrote the textbook *Polymer Processing Fundamentals*, Hanser Publishers, (1997). The textbook has been adopted at various universities around the world.

Re-developed ME 314, Material Processing - Fundamentals (2007)

This is a 7 week course taught two times a semester. It describes fundamentals of transport phenomena in material processing in a series of 14 lectures and 6 laboratories. This course is a required course in the mechanical engineering curriculum.

Revised ME 417, Introduction to Polymer Processing (1989).

The course describes the physical, thermal, and rheological properties of polymeric materials relevant to processing behavior. The basic transport phenomena equations are reviewed: mass, momentum, and energy. Analysis of various processing operations for the manufacture of polymeric articles, with particular emphasis on extrusion, injection molding, blow molding, thermoforming, and compression molding. Polymer recycling issues are also discussed. For this course Osswald wrote the Textbook *Polymer Processing - Modeling and Simulation*, Hanser Publishers, (2006). Parts I and II of this book will be used in this course.

Developed ME 718, Modeling and Simulation Polymer Processing (1991).

This course is designed to acquaint the student with computer simulation technology used for the engineering of polymer processes, such as compression molding, injection molding, extrusion, blow molding, and many others. The course reviews the basic equations of state, presents flow and heat transfer models used in polymer processing, and illustrates their numerical implementation using finite differences, finite elements, and boundary integral methods. The various numerical techniques are subsequently used to solve problems dealing with fluid flow, heat transfer, and structural development in polymer processing operations. For this course Osswald wrote the Textbook *Polymer Processing - Modeling and Simulation*, Hanser Publishers, (2006). Part III of this book will be used in this course.

Developed ME418, Engineering Design with Polymers (1995).

This course is intended to acquaint the student with a polymers' unique behavior and its relation to design. Molecular structure and basic properties are discussed. The relation between processing and properties of the final part are covered, as are mixing,

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anisotropy, and residual stresses during solidification. Important properties and the behavior of the polymer component are discussed: mechanical behavior, failure, optical properties, permeability, and electrical properties. For this course Osswald wrote the textbook *Materials Science of Polymers for Engineers*, Hanser Publishers, (1996), 2nd Ed. (2003). The textbook has been adopted at various universities around the world. The book was translated into Japanese and Korean.

Developed ME601 (ME420), Introduction to Composites Processing (2013)

This course is intended to acquaint the student with composites manufacturing processing. The course introduces basic physical, thermal, rheological and mechanical properties of composite materials and applies these to transport phenomena concepts to solve problems of flow through porous media, fiber orientation, curing reactions, shrinkage and warpage and mechanics of composites. Introduce laboratory material characterization experiments, CAE applied to composites product design, and apply these to a final group project for the design and manufacture of a composites product. The course is a 50-50 class-laboratory course with a strong design component.

UNIVERSITY DEGREES CREATED

Master of Engineering (Polymer Engineering and Science), College of Engineering, University of Wisconsin-Madison, Inaugural Class: Fall 1998, Degree Type: Interdisciplinary. Created with Professor A.J. Giacomin.

NON-ENGINEERING RELATED PAPERS AND BOOKS (HISTORY)

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2. Osswald T.A., *Hermann F. Mark*, *Plastics Insight*, (2), 11, 2000.
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9. Osswald, T.A., "In Search for the Right Books - A Historical Perspective of Polymer

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8. Michaeli, W., M. Mahlke, T.A. Osswald, and M. Nöhlke, "Simulation des Fließens bei SMC (Flow Simulation for SMC)," *Kunststoffe*, 80, 6, 717-721, 1990.
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EXTENSION/OUTREACH/SEMINARS

Extrusion Seminar at UW-Milwaukee Extension
Manufacturing with Plastics - College for Kids Workshop at UW

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Basic Manufacturing Engineering - Engineering Professional Development at UW

Polymers 101 - Engineering Professional Development at UW

Modeling in Polymer Processing - LKT, University of Erlangen, Germany

Simulation in Polymer Processing - LKT, University of Erlangen, Germany

Molding Processes Simulations - Neue Materialien Fürth GmbH, Germany

Polymer Processing - ICIPC, Colombia

Polymer Physics for Engineers - ICIPC, Colombia

Presents several seminars and courses at various industries and institutes in German, Spanish and English.

PROFESSIONAL SERVICE

1. International and National Committees and Boards

International advisory committee member of the International Society for Boundary Elements. 1994-2001.

Co-chair of the 17th International Boundary Element Conference sponsored by the International Society for Boundary Elements. (1995)

Editorial Board of *Engineering Analysis with Boundary Elements*. 1996-2001

Board of the Society of Plastics Engineers – Extrusion Division. 1997-2000

Editor for the Americas of *Journal of Polymer Engineering*. 1998-present.

Chief English Language Editor (Prof. G.W. Ehrenstein, Chief German Language Editor) for the *Journal of Polymer Technology (Archival Journal of the WAK)*, 2005-present

Editorial Board of *Journal of Composites Science*. 2017-Present

Editorial Board of *Polymers*. 2019-present

Editorial Manager for *Science and Engineering of Composite Materials*

Advisory Board of Hanser Publishers, 1998-present.

Professor Tim A. Osswald

Technical Advisory Board Member, Teel Plastics, Baraboo, WI, 2009-present

Scientific Advisory Board, SABIC, 2016-present

Editor of Polymer Composites (SPE archival journal) 2021-present

Scientific Advisory Board Member, RWTH-Aachen (Technical University-Aachen), Cluster of Excellence Integrative Production Technology for High-Wage Countries, Aachen, Germany, 2011-present

Editorial Board of *Journal of Science and Engineering of Composite Materials*, 2016-present

2. Professional Society Memberships

Polymer Processing Society (Treasurer)

Society of Rheology

Society of Plastic Engineers (Fellow)

ACS - Rubber Division

WAK, Scientific Alliance of Polymer Technology Professors

3. Technical Reviewer Activities

National Science Foundation

1990-present Have served one review panels yearly in the DMII Division, Engineering Directorate

Reviewer for the J. of Non-Newtonian Fluid Mech

Reviewer for the Int. J. of Polymer Processing

Reviewer for the Ohio Supercomputing Grant Awards

Reviewer for ASME WAM papers

Reviewer for ASME J. of Engineering for Industry

Reviewer for Int. J. of Polymer Proc., and Polym. Eng. and Sci.

Reviewer for J. Polym. Composites.

4. Faculty Advisor

Theta Tau Professional Fraternity

Society of Hispanic Professional Engineers (SHPE)

Society of Plastics Engineers